COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

AUG 29 1944

August, 1944

Main facade of Puerto Nuevo Power Plant

Puerto Nuevo Power Plant in Buenos Aires

Treatment of Water for Pressures Above 400 Psi

Combustion Calculations by Graphical Methods —REFINERY GAS

Designed and Built by

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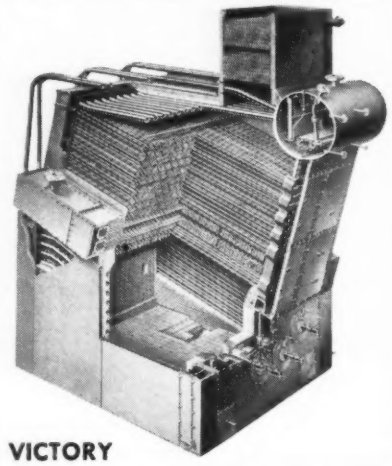

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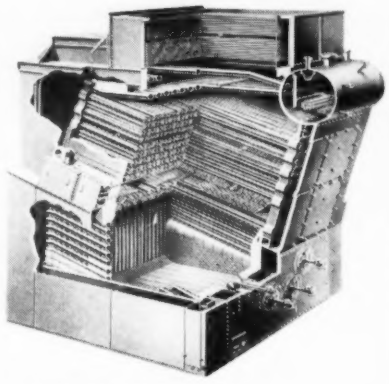

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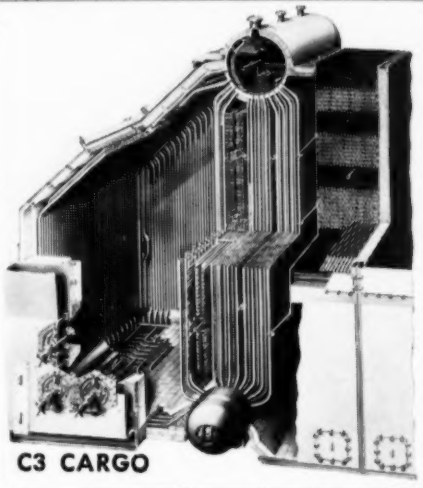

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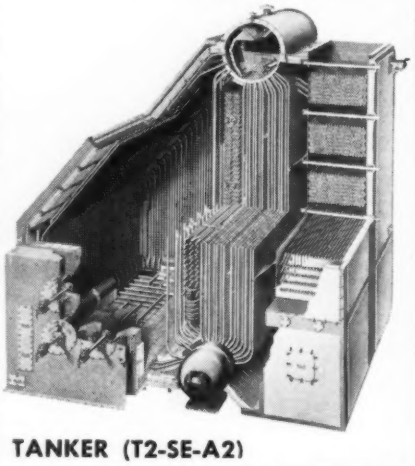

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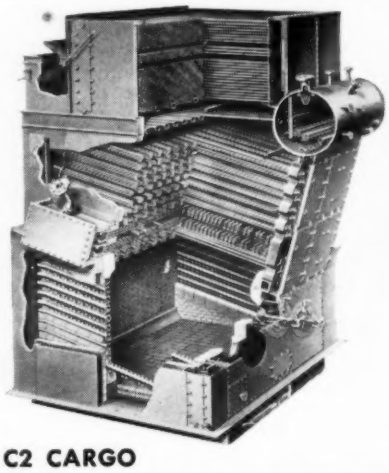

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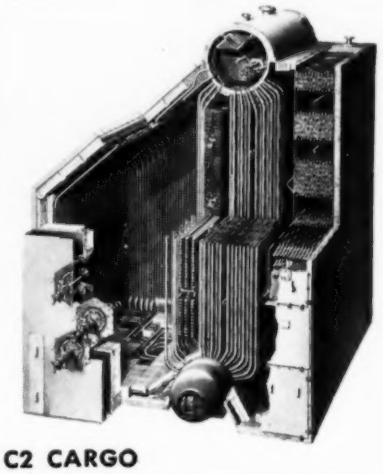

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COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

VOLUME SIXTEEN NUMBER TWO

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H. STUART ACHESON, *Advertising Manager*

ALFRED D. BLAKE, *Editor*

THOMAS E. HANLEY, *Circulation Manager*

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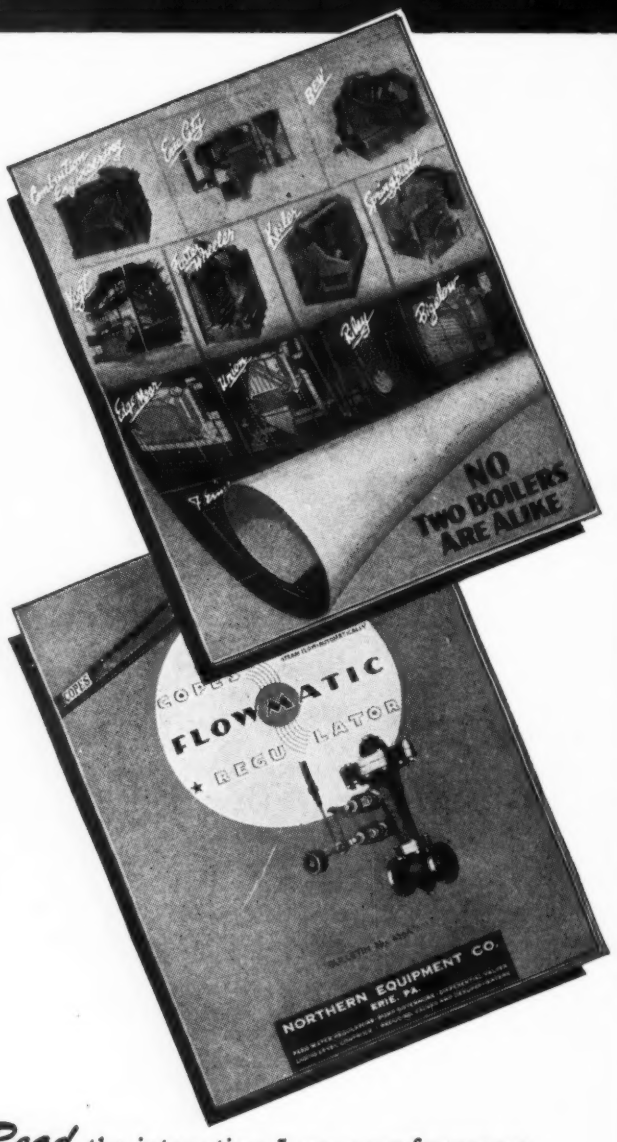

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EDITORIAL

Designing for Wide Range in Coal Characteristics

A major problem in furnace design, under modern operating conditions, is that of coping with the ash so that slagging may be controlled. Reliance upon premium coals of relatively low-ash content and high ash-softening temperature is no longer possible. Under the existing situation, metallurgical and certain other processes have first call upon such coals and their transportation is also a factor. Moreover, well-informed opinion is that their availability for steam generation will continue to be limited in post-war days and that price differentials are likely to be even greater than at present. Hence, one must anticipate purchasing from a wider range of coals and provide the necessary flexibility for their use. This, in general, points to larger furnaces if slagging troubles are to be minimized.

In discussing this problem at the recent A.S.M.E. Semi-Annual Meeting in Pittsburgh, E. C. Payne, of Consolidation Coal Company, pointed out that equipment which will permit reasonably wide latitude in fuel purchasing must be liberally designed. He cautioned further that purchase of combustion equipment on the basis of low first cost is a short-sighted policy.

A little figuring will demonstrate that the extra cost of an ample furnace is likely to pay for itself in a year or less not alone in fuel cost but also in labor saving, maintenance and improved availability.

Free Enterprise vs. Regimentation

Dr. G. S. Benson, President of Harding College (Arkansas), attributes our contribution toward winning the war through vast production, to years of free enterprise which, when brought to the crucial test, has been able far to outstrip the Axis system of regimentation, despite twelve years of intensive preparation. As he expresses it, "subservience to the thinking of a centralized government in Germany has dulled individual initiative and caused the masses to grow torpid from being bullied." In other words, he considers obedience as no substitute for wits.

It is true that, once in the war, this country found regimentative measures necessary, but these were able to take advantage of the products and methods of free enterprise, and to employ the thinking, experience and more particularly the initiative and resourcefulness that went with it. Moreover, the structure of the American system, coupled with our productive resources, were capable of almost unlimited expansion.

Agreement is general that in the reconversion period, and to some extent thereafter, a limited amount of governmental coordination will be desirable to cope with conditions brought about by the war which were previously nonexistent. But, it would be most unfortunate if certain of the wartime controls were continued to the extent desired by some for selfish reasons or by others from a distorted philosophy. Management must be given the opportunity of devoting more time to specific industry problems and to production unhampered by multitudinous regulations.

The U. S. Chamber of Commerce has just approved an eleven-point program of action for American business, looking to a quick ending of the war and early removal of obstacles to full post-war economic development. While encouraging continued industry cooperation with government agencies administering necessary wartime controls, it urges shifting as rapidly as possible to reliance upon competition and expanded production of civilian goods; also, it stresses early reduction in the size and scope of government supervision and resistance to the encroachment of federal functions upon those which are proper to the states and localities.

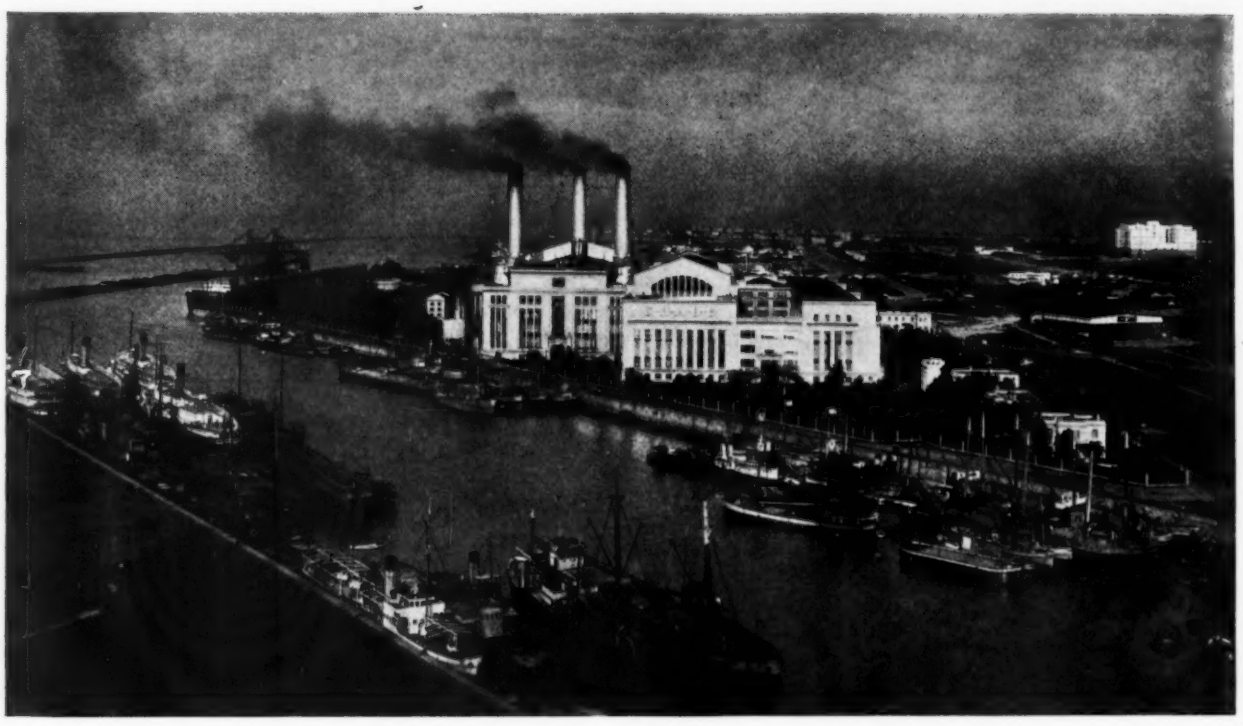
With the advent of peace, the sooner these objectives can be attained, the sooner will we be on the road to a restoration of the American system of free enterprise, individual opportunity, and further advancement in standards of living.

Influence of American Engineering Practice Abroad

One very probable aftermath of the war is that American practice in many lines will have been implanted in numerous foreign countries. This will range from minor items introduced through catering to the customs of our armed forces, to heavy equipment and productive machinery. Much of this, such as construction equipment, rolling stock, materials-handling equipment, large machines and power equipment, will have resulted from "lend-lease" and some from direct orders to fulfill post-war needs. It will play an important rôle in the rehabilitation of devastated regions and their re-establishment of industrial operations.

In the more backward countries, which have heretofore depended so largely upon manual labor, this should presage a new economic era with an advance in standards of living. In countries that are already industrialized, the effect is not likely to be so marked, but practice will be influenced.

It is beyond prediction to say to what extent this will result in future markets for American products in the fields mentioned in the face of foreign competition after conditions have again become settled, but it is certain that American-made equipment will have played such an important rôle in the rehabilitation of some countries that the influence will be long felt.



General view of station, with the City of Buenos Aires in background

PUERTO NUEVO POWER PLANT in Buenos Aires

By L. LE PAIGE, Ch. Engr., Amitas Ltd.

This is one of the largest and most important steam-electric stations in South America, with a present rated capacity of 262,000 kw. Originally placed in operation in 1928, its capacity has been extended in five steps, the latest unit having been put in service in 1942. The earlier section contained equipment largely of European manufacture, but the last section contains both European and American equipment. The boilers are normally fired with pulverized coal, but war conditions having interfered with the importation of coal, it became necessary to resort to the burning of various vegetable products.

COMPANIA Argentina de Electricidad (CADE) is the most important public utility distributing electricity in the City of Buenos Aires, Argentina, having supplied in 1943 1,675,000,000 kwhr of electric energy in the City and Province of Buenos Aires, including the 30-mile distant city of La Plata. The peak load reached during that year was 350,000 kw. This service is furnished by two main power plants—Dock Sud of 300,000 kw capacity and Puerto Nuevo of 262,000 kw capacity, and a couple of small plants.

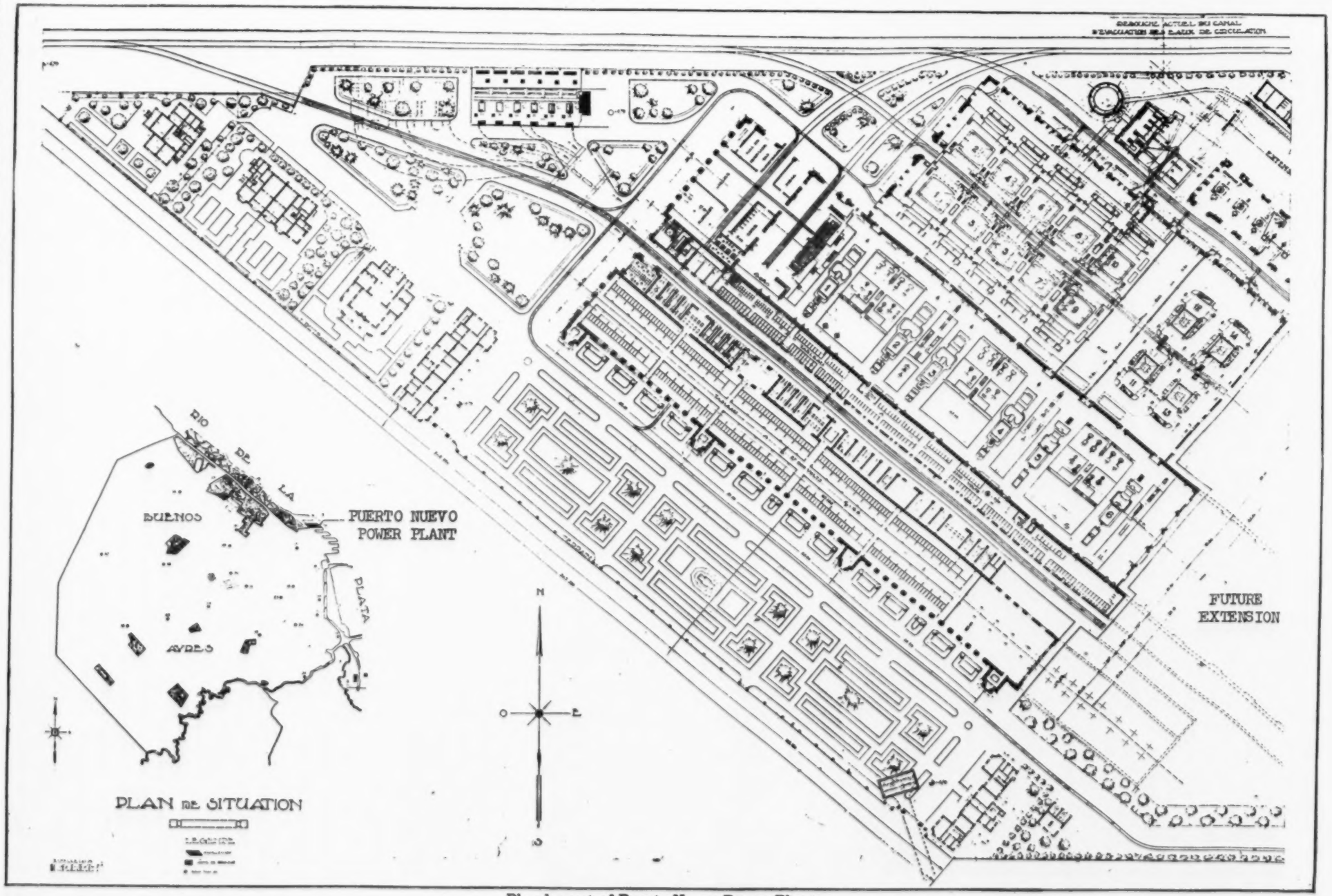
In normal times, Dock Sud is mainly used for handling peak loads on the main 50-cycle system, and also to supply a 25-cycle system, which is of secondary importance.

The Puerto Nuevo plant was projected in 1925 by Société Financière de Transports et d'Entreprises Industrielles Sofina, Brussels, Belgium, acting as consulting engineers and purchasing agents for many other public utilities in Belgium, Mexico, Portugual, etc.

The first section of this plant included four 52,500-kw turbine-generators, which were respectively put into operation in 1928, 1929, 1931 and 1934, the successive extensions being made according to the initial plans. In 1938 studies were begun for a second section, incorporating several new features, and the first unit was started in 1942.

In the present description the following points will be dealt with in order:

1. Location and conditions which influenced the general layout of the plant, such as buildings, cooling water and fuel supply.
2. Summary description of the first section of the plant and general principles adhered to in the planning of this section, as well as of the 1942 extension.
3. Description of the 1942 extension, stressing in particular all new features characterizing its equipment.
4. Figures in regard to heat consumption.
5. Some facts relative to the present operation of CADE plants with substitute fuels.



Plan layout of Puerto Nuevo Power Plant

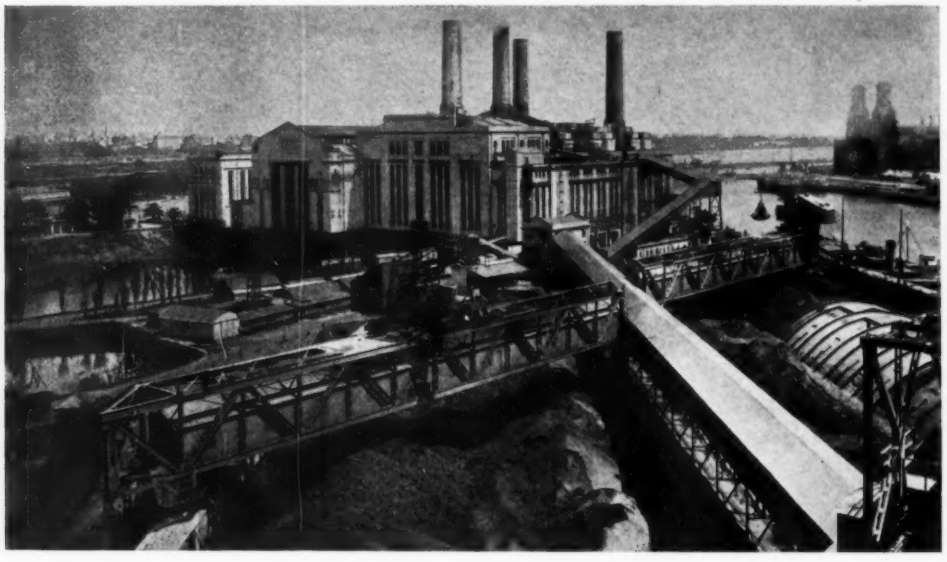
Location, Buildings and Fuel Supply

Puerto Nuevo plant was built on a 35-acre property, entirely recovered from the Rio de la Plata river bed. The site is in the shape of a parallelogram 1920 ft long by 1220 ft wide, with an acute angle of 40 deg. This particular shape was imposed as a condition by the port authorities, and affected the general layout and especially the relative locations of the turbine room and the boiler room, the latter being disposed parallel to the first, with the boilers grouped in two rows facing a central firing aisle.

Recovery of the land was carried out by encircling it with a cofferdam, pumping it dry, and building the quay walls, the water inlet and outlet tunnels, and the foundations; and then removing the cofferdam and filling up to the extent initially required. Further filling was done later by utilizing for this purpose the ashes produced by the plant.

pany has several tanks of its own in a section of the harbor reserved for inflammable products. Transport from there to the plant is by barge.

Under exceptional conditions of river flow, tide and wind, the level of the Rio de la Plata may rise as much as 15 ft above or fall as much as 12 ft below the average level. Therefore, the ground line had to be located at elevation 15 ft 7 in., that is, higher than the highest recorded level of the river; and, on the other hand, measures had to be taken so that under all conditions the cooling water supply would be assured to the condensers. For this reason the circulating pumps are located in pits adjacent to the water-inlet tunnel, the bottom of these pits being at elevation −25.0 ft. The suction of these vertical circulating pumps is located at elevation −18.5 ft, in order that a positive suction head on the pumps may be insured under the most unfavorable conditions. The pump motors are located at elevation 13.2 ft. Water is brought to the pumps and carried back



Station viewed from east, showing fuel storage and handling

The main buildings, turbine room, boiler room and switchhouse, are all parallel to one another. Along the northwest end of the turbine room are located the workshops, storage warehouses and sundry departments. A railroad track enters the turbine room within reach of the traveling crane.

The architectural design of the buildings, of which the picture on the cover of this issue gives an idea, was entrusted to Mr. Dhuicque, a Belgian architect. The steel structures were produced in Argentina, the frame design being adopted to eliminate diagonal bracing almost entirely.

All the coal that is burned has to be imported (it came mainly from Europe before the war) and is brought by seagoing colliers, a 30-ft depth of water being maintained along the quay walls. The coal is unloaded from the boats by two coaling cranes, each capable of handling 100 metric tons per hour. It is transported, distributed to the coal yard, and taken from there to be sent to the breaker house and the central pulverizing plant by two coaling bridges each capable of handling 200 metric tons per hour, and a system of transporting belts.

The boilers are also equipped for burning fuel oil. Because of certain regulations, only a small quantity of this fuel may be stored on the property, but the Com-

to the river through a system of tunnels. At the upstream end of the inlet tunnels there is a system of trash racks and traveling screens. Four traveling screens are installed at present. This installation is entirely outdoors, which is possible in a climate where frost is practically unknown. A gantry crane is available for maintenance.

First Section (1928)

The two units first installed in the 1928 Section were provided with intermediate steam reheat, as they were intended to be used for base load. The two other units, installed at a later date, which were intended for intermittent operation, are non-reheat machines. All these turbine-generators are International General Electric Co., 1500-rpm, two-cylinder machines and, with the exception of the reheat feature, they are identical. Each turbine drives, besides the 55,500-kva main generator, a 2500-kw auxiliary generator, as well as their respective exciters.

Steam conditions at the throttle in this section are: Pressure 550 psi, temperature 750 F, reheat 750 F. Each turbine has four bleed points for feedwater heating. All four heaters are of the closed type, two being located ahead of and two after the feed pumps. Feedwater is heated to 290 F.

In the condensate cycle of these units, the difference in output between the condensate and the boiler feed is taken care of by a system of float valves on the condenser hotwell and a surge tank open to atmosphere. If water has to be fed into the cycle, it is taken from the surge tank and injected into the condenser for deaeration.

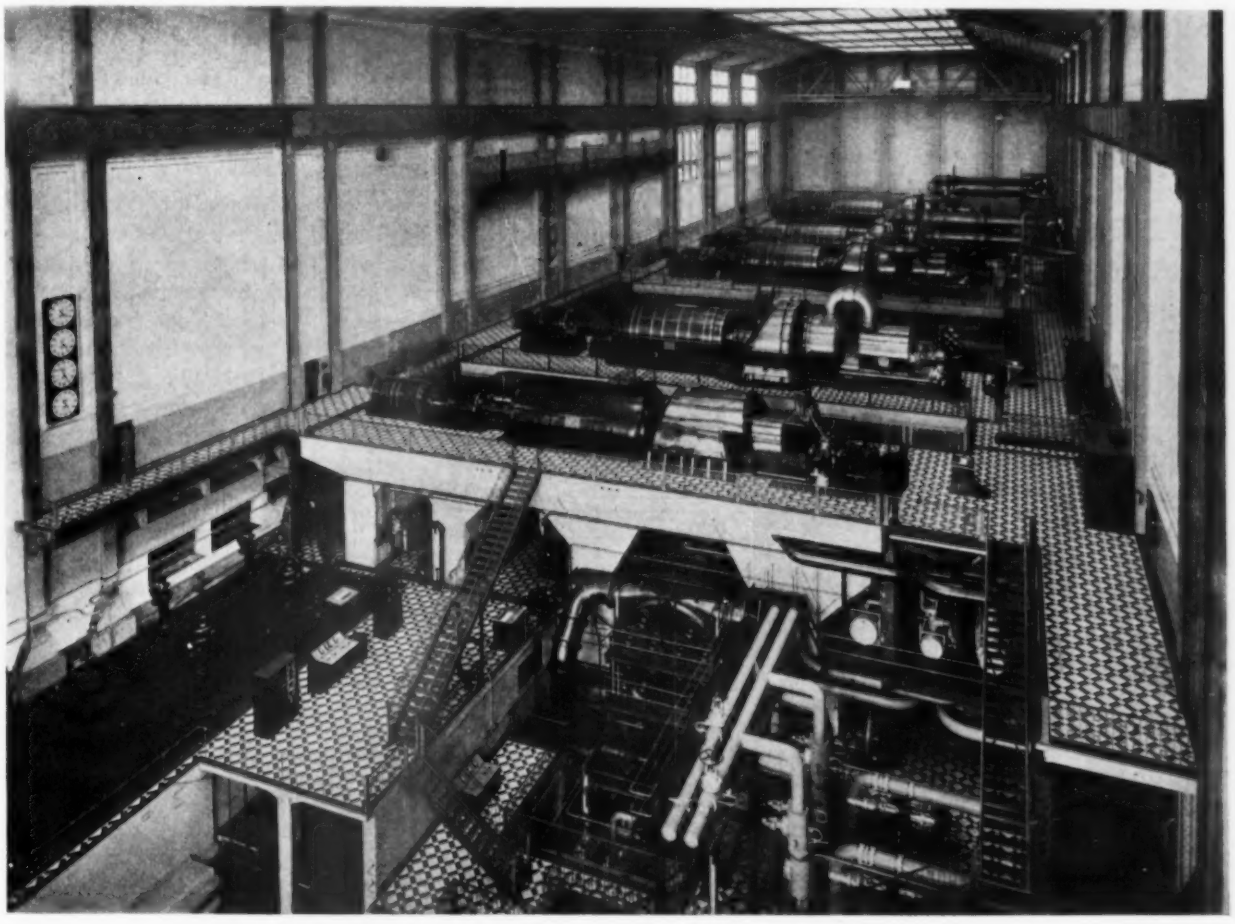
An ample supply of condensate is stored in tanks some of which are located in the boiler room basement and others on the building roof. The drains are piped into the lower tanks.

A feature of Puerto Nuevo is the distribution of the units in the turbine room. Machines 1 and 2 are 85 ft apart; 2 and 3 are 42.5 ft; 3 and 4 are 85; and 4 and 5 are 42.5 ft apart. In the 85-ft intervals are located all the auxiliaries of two adjacent turbines; also the feed pumps. The circulating pumps are installed in groups of four in the above-mentioned pits which open into the turbine room and are accessible to the traveling cranes. The condensate and feed pumps are duplicated, one being a spare.

All the units except one are provided with evaporators. Incidentally, it should be mentioned that the quantity of makeup used is very small, and is kept under 1 per cent.

The first section has ten sectional-header boilers, of which two are of the reheat type. The normal boilers are each capable of evaporating 235,000 lb of steam per hour and the reheat boilers 150,000 lb, and at the same time reheating the steam flow of a reheat turbine running at full load. The pressure parts of these boilers were supplied by Babcock & Wilcox, London, whereas the combustion chambers, air heaters and other accessories were supplied by International Combustion, London and Derby, England.

These boilers are fired with pulverized coal produced, as already mentioned, in a central pulverizing plant, and the burners are of the vertical fantail type. The back walls, roof, and part of the furnace side walls, have fin tubes, whereas the front wall is air cooled. The combustion chambers are provided with a hopper water screen, and the ashes collected in the hopper are removed by hydraulic sluicing. Each of these steam generators is equipped with an economizer and an air heater of the plate type.



View of main turbine room with auxiliary pit of latest unit in foreground

Between the boilers and the stacks, which have their top at elevation 246 ft, dust catchers of the cyclone type were installed and proved satisfactory until some years ago. However, because of the increasing load on the plant and the growth of the city, some of the cyclone separators have been replaced by electrostatic dust collectors, and the others will be replaced as soon as possible after the war.

The generation voltage is 13,200. Each turbine-generator is direct-connected to a set of three single-phase transformers, raising the voltage to 27,500 v, which is the bus-bar voltage. These transformers are cooled by circulation of oil which, in turn, is water-cooled. The bus-bars are subdivided into sections,

Piping diagram of turbine-generators Nos. 5 and 6

each section being fed by two generators corresponding to a capacity of 100,000 kw. The various electrical sections may be put in parallel either direct or through reactors. Outgoing feeders are at 27,500 volts.

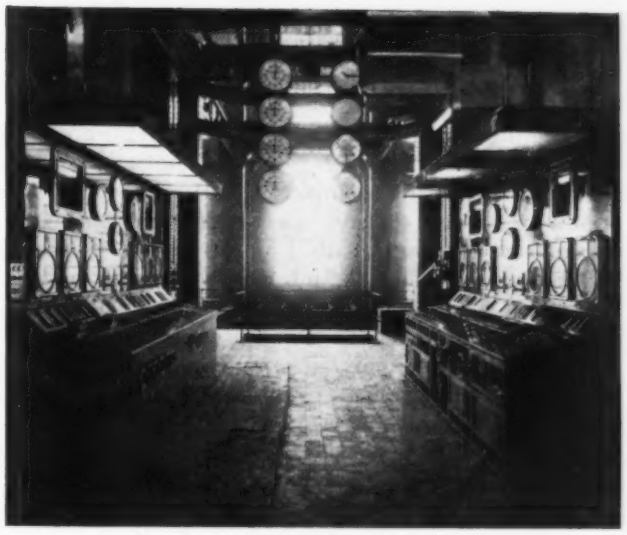
All auxiliaries of Puerto Nuevo are electrically driven, with the exception of three emergency feed pumps. Each of these has only half the capacity of one of the electrically-driven feed pumps, of which there are two per unit, each capable of handling a turbine's full load.

As previously mentioned, each turbine-generator is provided with a 2500-kw house generator, 0.8 power factor, operating at 2300 volts. All auxiliaries requiring more than 100 hp are driven by 2300-volt motors, the smaller motors operating on 550 volts. Each essential auxiliary may be connected to either of two sources of current, one being the house turbine-generator and the other a 27,500/2300-volt transformer connected to the main bus.

The turbine auxiliaries are arranged as follows: Normally one circulating pump is connected to one source and the second to the other. Both pumps are run and together serve the condenser. But in case of failure of one of the sources of electric supply, the condenser continues to be supplied by the other one. In order to insure this, non-return valves are located at the pump outlets. Interlocks, level or pressure relays of the extraction and feed pumps are so adjusted that if one of these pumps should fail, the spare, which is connected to a different source of current, will start automatically.

As regards the boiler-room auxiliaries, all fan motors can be supplied from both the above-mentioned sources, and in case one fails, automatic devices immediately connect the motors to the other source and bring them up again to the same speed at which they were working before. Of course, the normal sequence interlocks are provided.

View in furnace of boiler No. 12, looking upward



Control panels of two latest boilers

The forced- and induced-draft fans are each driven by two variable-speed motors, one driving the fan at the lower loads and the other at the higher loads. The primary air fans are driven by constant-speed motors. Coal feeders and fuel-oil pumps are operated by 440-volt d-c variable-speed motors, the direct current being produced by motor-generators in parallel with an amply sized storage battery.

1942 Extension

In 1938 studies were started for a new section which was to include two more 52,500-kw turbine-generators and four boilers. Larger machines were considered, but not adopted. Steam conditions were reconsidered, an extensive comparison being made between the following:

600 psi, 900 F
1200 psi, 900 F, without reheat
1200 psi, 900 F, with reheat

The first of these proved to be the most favorable, and it was decided to adopt it for Units 5 and 6, of which Unit 5, with two 285,000-lb per hr boilers, was to be installed immediately and Unit 6 with two identical boilers at a later date.

The new turbine-generator, supplied as the first by the International General Electric Co., differs in many respects from the previous units. It is a 3000-rpm, tandem-compound double-flow machine, the high-pressure section having one two-row wheel and 17 single-row wheels. The low-pressure section has four double-row stages. The turbine drives the main generator, the 2500-kw auxiliary generator and two geared exciters. Moreover, the main generator is hydrogen-cooled.

The heat cycle, although including also four extraction points, is different from that of the previous units in that it includes a direct-contact heater acting as deaerator. This deaerator is provided with a surge tank, the capacity of which corresponds to half an hour's output. The feedwater is heated to 340 F, thus to a higher temperature than in Section 1.

As to general arrangement, electric supply of auxiliaries and electric connections, the same general principles laid down since the beginning were closely followed.

The boilers of Section 2, supplied by the Combustion Engineering Company of New York, are entirely different from those of Section 1. They are of the three-drum bent-tube type with completely water-cooled furnaces and hopper water screens; they do not have economizers but are equipped with Ljungström air preheaters. The superheater is of the interbank type, the temperature of the steam at the superheater outlet being regulated by a damper under automatic control.

Each boiler has eight tangential coal burners located in the corners of the combustion chamber and combined with eight oil burners. The coal is supplied from the existing bin storage system. Heating surfaces are as follows:

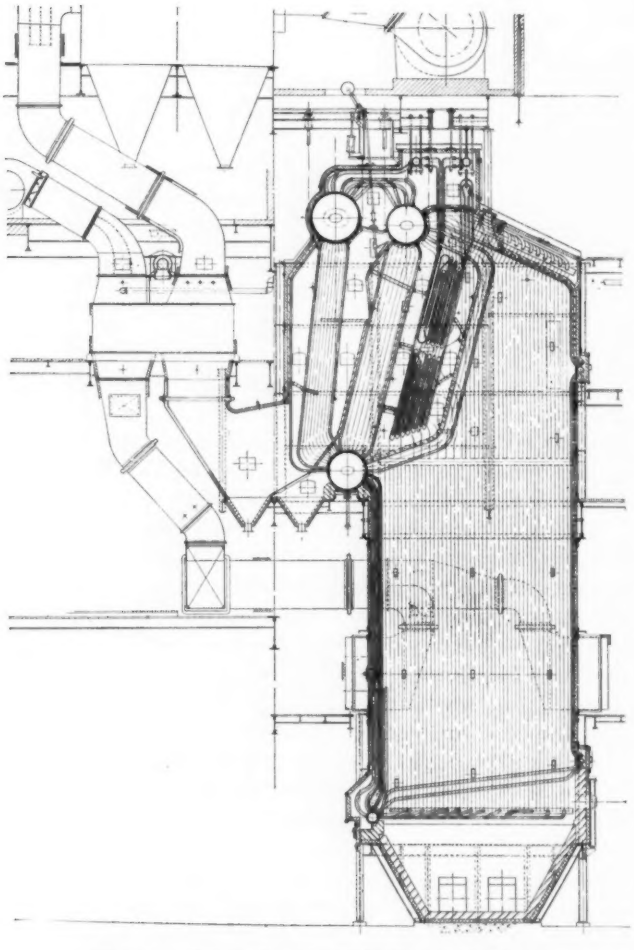
Boiler	15,000 sq ft
Furnace	5,708 sq ft
Superheater	9,270 sq ft
Air heater	44,100 sq ft

The volume of the combustion chamber is 15,500 cu ft.

The exact figures in regard to normal steam conditions at the superheater outlet are:

Pressure: 612 psi

Temperature: 905 F when fired with coal, between 46 per cent and 100 per cent full load



Section through one of the latest boilers

The feedwater regulators are of the three-element type. For ash removal the same system was adopted as in Section 1.

No innovations were made as to the method of driving the fans, feeders and fuel-oil pumps, although the respective electric equipment is of an improved type.

The new boilers have electrostatic precipitators and a common stack is provided for the removal of products of combustion from all four boilers of Section 2.

The piping of this Section is entirely welded, with the exception of the valve bonnets, which are bolted. Carbon-molybdenum steel was used for the high-pressure steam system, the welds being preheated and stress-relieved. A connection through a pressure regulator and a desuperheater is provided between the high-pressure steam headers of Sections 1 and 2.

The main pieces of equipment for the extension were ordered in 1939. The turbine was placed in operation in May 1942 with one boiler. The other boiler was started in August of that year.

After the invasion of Belgium, technical services were provided by Amitas Ltd., New York.

Performance Figures

Some figures as to economy and availability may prove of interest:

Year	1939	1940	1941	1942	1943
Installed capacity, kw	210,000	210,000	210,000	210,000/262,000	262,000
Production (Millions of kwhr)	1,039	1,150	1,127	1,015	1,224
Btu. per kwhr generated*	12,257	12,380	12,296	12,923*†	12,578*†

* Referred to *lower* calorific value, as is usual in Europe.

† Increase is ascribed to the use of substitute fuels and troubles resulting therefrom.

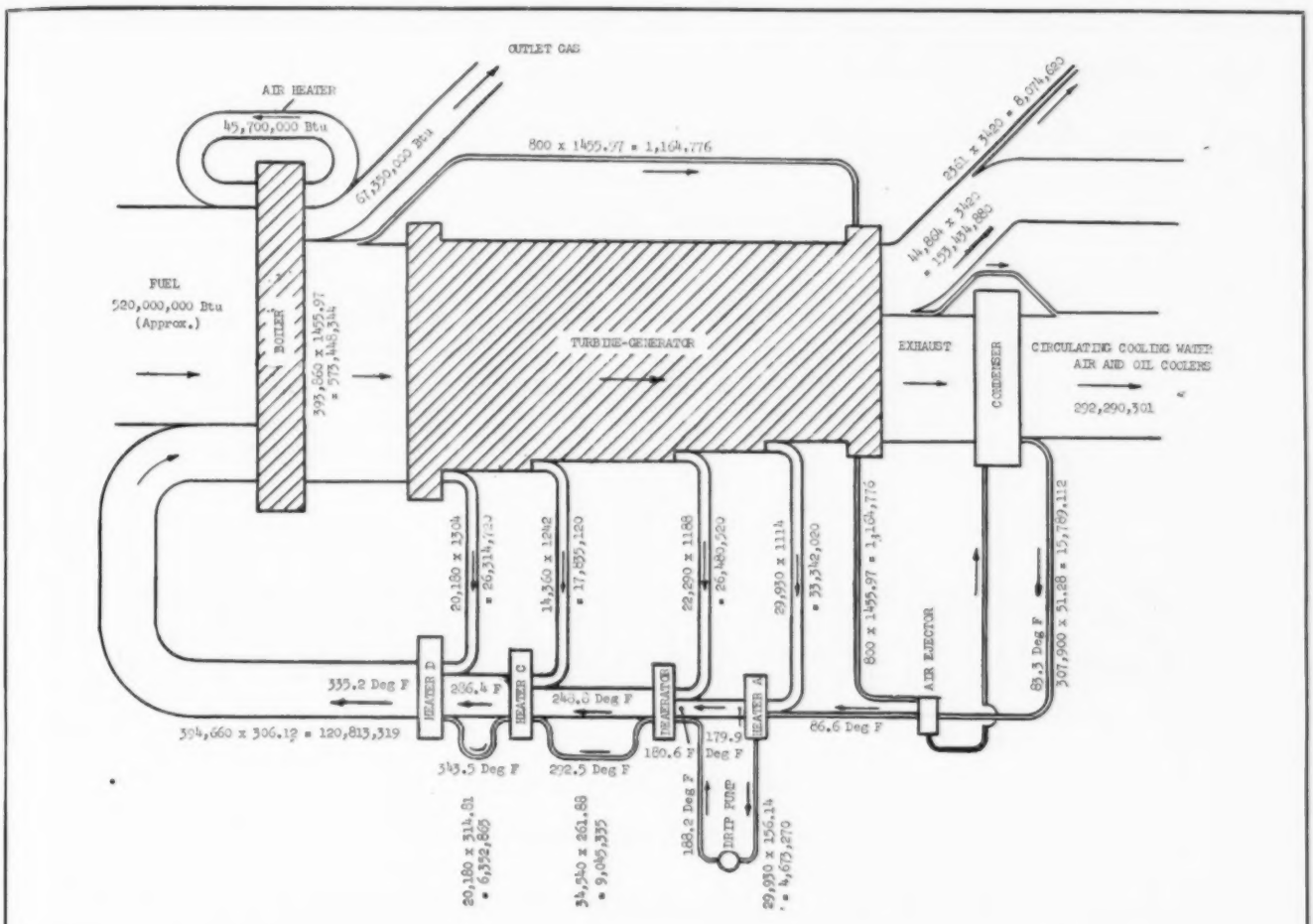
The two first installed reheat units (Nos. 1 and 3) had operated on December 31, 1943, respectively, 120,507 and 119,874 hr and produced 4,558,592,000 and 4,579,698,000 kwhr.

Operation with Substitute Fuels

At the beginning of the war CADE had stored a large amount of coal, both in the yards generally used for that purpose and in emergency piles. In the first months after the outbreak of war some coal was still received from Great Britain and from the United States, as well as some fuel oil. However, in the course of 1941, the shipments received fell far short of the consumption, and the stocks began to dwindle. In order to conserve them as far as possible, it became necessary to use all kinds of vegetable fuels, such as corn, wheat, linseed, charcoal and linseed oil. These products, with the exception of charcoal, are normally essential items of Argentine exports, but could no longer be sold on the foreign market because of the shipping shortage.

At Puerto Nuevo, corn, wheat and linseed were burned in pulverized form. Some mills adapted for grinding them were purchased in the United States and others were built at the site. These mills feed direct into home-made burners, working thus according to the principle of individual pulverizers. Charcoal is mixed with some coal, pulverized in the existing pulverizing plant, and distributed and burned by means of the equipment in use for the normal coal.

The approximate calorific values of coal (13,500 Btu), corn (6,750 Btu), wheat (6,750 Btu), linseed (10,000 Btu) and charcoal (11,800 Btu) compare as follows:



Unit heat-flow diagram at economical load of 47,225 kw (evaporator not operating)

1—0.5—0.5—0.75—0.88. The ash content of the vegetable fuels is low, but it consists essentially of alkaline phosphates, which melt at a low temperature, acting as flux, attacking the refractories and occasioning bird-nesting; and, as can readily be understood, they lead to operating and maintenance troubles.

At Dock Sud the same substitutes are burned on the existing stokers, the speed of which has been increased. There, linseed oil is burned with the equipment normally used for bunker oil.

Use of these substitutes reduces the efficiency and the availability of the boilers. The combined effect of both evils corresponds to a loss in steam production of 30 to 40 per cent. Two new boilers for Puerto Nuevo and two others for Dock Sud, ordered in the United States, could not be obtained because of war conditions; hence reserve boilers had to be called into daily use.

Below is a summary of the quantities of various fuels used in 1942 and 1943:

1942		
Coal	181,200 metric tons	(2205 lb)
Fuel oil	129,000 metric tons	
Corn	785,700 metric tons	
Charcoal	121,800 metric tons	
Miscellaneous	3,400 metric tons	
1943		
Coal	169,400 metric tons	
Fuel oil	56,800 metric tons	
Wheat	319,500 metric tons	
Corn	16,100 metric tons	
Charcoal	186,400 metric tons	
Linseed	292,900 metric tons	
Linseed oil	37,950 metric tons	
Linseed oil cake	13,300 metric tons	
Miscellaneous	9,450 metric tons	

PRINCIPAL EQUIPMENT USED IN THE 1942 EXTENSION

Turbine-generator Rating 52,500 kw (Maximum 57,400 kw) 3000 rpm Steam conditions, 579 psi, 887 F	*International General Electric Company*
Condenser, two-pass divided water boxes; surface 36,200 sq ft Circulating pumps Extraction pumps Air ejectors, deaerator Boiler feed pumps	*Worthington Pump & Machinery Corporation*
Closed heaters, evaporator Evaporator-condenser	*Foster Wheeler Corporation*
Two steam generators 285,000 lb per hr at 612 psi, 905 F with Elesco superheaters, Ljungström air heaters and American Blower Co. fans	*Combustion Engineering Company*
Flue-dust precipitators	*Western Precipitation Corporation*
One 15-ton per hr Raymond roller pulverizer and accessories	*International Combustion Ltd., London, England*
Pipework	*M. W. Kellogg Company*
Valves	*Crane, Edwards, Atwood-Morrill, Fisher, etc.*
One 62,500-kva bank of 3 single-phase transformers 13/27.5 kv	*Metropolitan Vickers, Manchester, England*
One 6000-kva 27.5/23-kv transformer	*Metropolitan Vickers, Manchester, England*
One 1000-kva 2300/550-volt transformer	*Brown Boveri, Baden, Switzerland*
27.5-, 13.2-, 2.3-kv electrical equipment	*International General Electric Company*
Motors, starting and speed regulating devices—440 volts d-c equipment	*International General Electric Company*
2.3-kv boiler-room metal-clad switchgear	*Reyrolle, Hebburn-on-Tyne, Great Britain*
Instruments	*Bailey Meter Company* *Foxboro* *Leeds & Northrup, etc.* *Ashcroft*
Circulating water valves	*Blakeborough & Sons, Brighouse, England*
Tank pumps	*Yeomans Brothers, Chicago, Ill.*
550-volt, three-phase equipment	*Brown Boveri, Baden, Switzerland*

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Treatment of Waters for Pressures Above 400 Psi

By R. E. HALL

Director, Hall Laboratories, Inc.

These notes are from a discussion by the author at a symposium on water treatment at the recent Annual Meeting of the A.S.T.M. The view is expressed that rate of heat absorption is a better criterion than operating pressure.

IS 400 psi operating pressure a logical basis on which to make distinctions of treatment? Are not such distinctions better based on rate of heat input to the evaporative surfaces than on a few pounds per square inch of operating pressure one way or the other; or, on the ratio of the density of liquid and vapor, a figure indicative of the driving force of steam bubbles in promoting circulation?

In classifying or interpreting water analyses consideration must be given particularly to the small users and the small power plants, since large users and large power plants will have their experts on water to guide them. Any approximations or simplifications, however, must apply in all cases.

In attempting to answer these questions, the author will start with principles applicable to all operating pressures, dealing thereafter with more specific conditions.

In addition to deaeration, which is mechanical, two distinct considerations are involved in any treatment of waters to be used in generation of steam; these are:

1. Limitation of Impurities in Steam

Steam of all pressures terminates similarly with condensation to water. Hence in all cases, impurities in the original water must be manipulated in such a manner as to prevent their imparting detrimental deposit-forming or corrosive qualities to the steam. Organic contamination which promotes carryover of boiler water in the steam, ammonia, carbon dioxide, and silica are the principal offenders. Exceptions to this general principle are those cases in which the steam condenses without contact with metal conduits which guide the flow of condensate, for example, by being exhausted to atmosphere. But in all cases in which effort is made to save the condensate, or in steam heating, whether the condensate is saved or not, these principles apply.

2. Character of Boiler Water

In the boiler water provision must be made for two drastically different sets of conditions as follows:

(*a*) Those characterizing the dilute overall boiler water, whose concentration of dissolved and suspended components may be controlled as desired by blowdown. The alkalinity relationship and the concentration of treating chemicals to be maintained therein, also the various types of pretreatment best suited and commercially available for the raw waters to be used, have been widely discussed in the engineering literature and can be omitted here. As a part of its work in interpreting waters or arriving at some classification of them, the committee cooperating with the Boiler Feedwater Studies Committee (A.S.M.E.) might well agree upon some maximum concentration of total solids to be maintained in the boiler water; perhaps 2500 ppm or even 3500 ppm for pressures below 400 psi, and perhaps 1500 ppm for pressures above 400 psi. The author emphasizes, however, that in any such recommendations, the question again becomes paramount whether rate of heat absorption may not be a better criterion of the dividing line than operating pressure.

(*b*) Those conditions obtaining as the overall boiler water or films thereof evaporate and concentrate at steam-water interfaces and of any boiler water carried mechanically by the steam into the superheater. The concentration of dissolved solids therein attained at equilibrium has no dependence on blowdown, but, instead, is a function of temperature increment at the interface, boiler pressure, and the behavior of the dissolved solids in relation thereto. The extent to which these conditions obtain is more influenced by rating or by circulation than by pressure.

Available Carbon Dioxide

It might be well to list as one item of the analysis, the carbon dioxide available in the bicarbonate and carbonate radicals found in the water, since in boiler use, some, and at times much of this, may find its way into the steam. Dependent upon the temperature at which the feedwater heater operates, and also on its venting, some decomposition of the bicarbonate radical will occur with loss of carbon dioxide, presumably to the extent of 30 to 50 per cent. If the final equilibrium in the boiler water is maintained by treatment with phosphate, practically all of the carbon dioxide carried into the boilers, except that small portion lost in blowdown, will be evolved into the steam. If there is no treatment of the boiler water, part of the available carbon dioxide will be precipitated as calcium carbonate. If the boiler water is maintained alkaline by use of sodium carbonate, considerable carbon dioxide will be provided in the steam by decomposition thereof.

If a maximum limit to carbon dioxide in the steam were to be stipulated at, say, 15 ppm, which corresponds approximately to its concentration in steam made from lime-soda treated water, it then would become possible to estimate roughly whether or not the water requires external treatment, and the permissible types of treat-

ment. Thus, assuming 50 per cent loss of the available carbon dioxide through the vent of the heater, the following relationship may be established:

$$\text{Available } CO_2 \text{ ppm} \times 0.5 \times \text{per cent makeup water}/100 = 15$$

If the value found is equal to or less than 15, external treatment may be omitted, unless the value of total hardness as $CaCO_3$ considerably exceeds that of the HCO_3 radical; in other words, unless permanent hardness largely predominates. In that case, dependent on the amount of the permanent hardness, treatment for hardness removal by any of the standard commercial methods may be advisable. If the value found is greater than 15 and the value of total hardness as $CaCO_3$ is comparable to or greater than that of HCO_3, it becomes advisable to treat the water by a process which simultaneously effects removal of hardness, and elimination of available CO_2 to the extent required for its proper limitation in the steam. Only in the case of high value for HCO_3 and low for total hardness as $CaCO_3$ is simple elimination of CO_2 by acid treatment alone advisable.

In a great number of cases the maximum of 15 ppm of CO_2 in the steam will be considered too high, a minimum of as little as possible frequently being the objective. These cases will represent mostly larger operations, however, usually with skilled personnel available for interpreting waters.

Approximation of Blowdown

If a general criterion is established for permissible total solids in the boiler water, the items in the analyses of dissolved solids and total hardness as calcium carbonate provide simple means of approximating the blowdown required. If the natural water is one in which suspended matter to any extent is usually present, it should be filtered. If the water is subject to occasional periods of turbidity, then, as required, the blowdown can be adjusted to take cognizance of the turbid condition, or filtration can be provided, as justified by the severity of the occasional turbidity.

If no treatment of a water is contemplated, then blowdown in per cent, calculated on the basis of feedwater, may be approximated as follows:

Below 400 psi: Blowdown = (dissolved solids, ppm/3500) × per cent makeup

Above 400 psi: Blowdown = (dissolved solids, ppm/1500) × per cent makeup

If treatment in the boiler is contemplated, the approximate per cent of blowdown on the basis of feedwater becomes:

Below 400 psi: Blowdown = [(dissolved solids, ppm + hardness as calcium carbonate, ppm)/3500] × percent makeup

Above 400 psi: Blowdown = [(dissolved solids, ppm + hardness as calcium carbonate, ppm)/1500] × per cent makeup

In the case of external treatment, no general considerations on blowdown are possible until after a decision has been reached regarding the type of treatment to be used, in accordance with the requirements of limiting carbon dioxide in the steam, as discussed above.

Sludge Content of Boiler Water

How much sludge can be tolerated in the total solids of the boiler water? Quite frequently a limit is given thereto in terms of per cent of the total solids. With such a limit established, and with the amount of blowdown known, it becomes a simple matter to calculate approximately the sludge that would be present in the boiler water from the figure of hardness as calcium carbonate in the analysis; thus:

Sludge (in boiler water), ppm = Hardness as calcium carbonate × per cent makeup/per cent blowdown(on feedwater)

Color and Carryover

One other factor of the analysis becomes of value in calculations of this type. When concentrated in the boiler water, the natural organic contamination of a water as measured by color is usually decidedly contributory to contamination of the steam by carryover. An approximate measure of this effect for the conditions of any one case is given by

Color (in units reported) × per cent makeup/per cent blowdown (on feedwater)

If the value thus obtained exceeds some standard value agreed upon, the advisability of treatment for removal of the contamination is thus clearly indicated. Where evaporators are used, and their brine is treated, consideration of this factor becomes important in the avoidance of carryover and the concurrent addition of impurities to the evaporated makeup.

Sufficiently effective carbon dioxide removal can be accomplished by lime-acid treatment, or by sodium-hydrogen-zeolite. Treatment by lime-acid will result in considerably higher total solids than treatment by sodium-hydrogen-zeolite, the former, therefore, necessitating higher blowdown value. On the other hand, backwashing and rinsing of the zeolite requires considerable water. In this case, decision must be reached whether it is better to accept the higher blowdown required by the lime-sulphuric acid treatment than to obtain the lower blowdown of the sodium-hydrogen-zeolite at the expense of the water necessary for backwashing and rinsing. Besides, if necessary in spite of high blowdown, reduction of silica can be effected as part of the regular procedure.

Higher Operating Pressures

In general, as operating pressures are higher, the trend is toward more complete removal of all impurities in the water to be treated, as by evaporators, or by anion-cation exchangers. This applies especially where condensate is available in considerable percentage, as in utility plants. In this way, impurities in the boiler water, other than chemicals added as treatment, are limited in origin to evaporator carryover and condenser leakage plus incidental foreign material which drifts into the system as it operates, but which can be held to low values with care. In industry, however, this trend, while apparent, is not so prevalent, particularly through the pressure range of about 900 psi, or higher in some instances.

The typical characteristics of the dilute overall boiler water for pressures above 400 psi are not markedly different from those recognized as satisfactory for pres-

sures below 400 psi. Where the boiler water is kept very pure by the use of evaporated makeup, and by holding condenser leakage to a minimum, lower alkalinities are permissible, but if the percentage of treated makeup is considerable, and total solids in the boiler water and separation of sludge are greater, alkalinities much in line with those held for pressures below 400 psi are advisable. Usually, the total solids in the boiler water, and the percentage of sludge therein, are maintained lower the higher the operating pressure.

Even with these things done, troubles develop. Scales containing silica or analcite or acmite develop, particularly under any layers of sludge that may form in tubes where the evaporative rate is high. Iron-oxide sludges accumulate in the boilers, and tubes become pitted or channeled through loss of metal by combination with the bonded oxygen of the boiler water. These troubles develop as films of the overall boiler water evaporate and concentrate at steam-water interfaces. This occurs independently of the concentration of dissolved solids in the main body of the boiler water, and is dependent upon temperature increment at the interface, upon boiler pressure and upon the physical-chemical characteristics and the relative proportions of the dissolved solids in the boiler water. Such conditions develop more commonly in boilers of higher pressure, although they may occur in boilers of lower pressure where the heat input is exceptionally high.

Why are these effects more pronounced in boilers of higher operating pressures? To answer the question, let us consider some of the factors associated with the generation of a cubic foot of steam, at 400 psi, and at pressure intervals of 800 psi. The temperature of saturated steam generated at these intervals of pressure is as follows:

Pressure, psi	Temperature of saturated steam
0	212
400	448
1200	569
2000	637
2800	686

The temperature increase with change in operating pressure from 0 to 400 psi is 236 deg F; that from 400 to 2800 psi is 238 deg F. Over this temperature range, the solubilities of the boiler-water salts undergo change. Some, like sodium chloride and sodium hydroxide, increase in solubility; others, like sodium sulphate, sodium phosphate and sodium silicate, decrease in solubility. But increase in temperature in the overall boiler water in itself is not enough to account for the development, on the one hand, of hide-out and, on the other, of hard deposits such as sodium silicate, sodium aluminum and sodium iron silicate, with lesser amounts of sodium sulphate and sodium phosphate.

If a film or thin layer of boiler water which, as a steam bubble forms, remains in contact with the evaporative surface of the tube, and if the temperature of the latter on the water side is raised a few degrees above that of the saturated steam, deposition of sodium salts of inverse solubility is readily explained. In such a film, high concentration is developed by substances whose solubilities increase with increasing temperature. Thus, such increase in concentration of caustic soda readily promotes the formation of magnetic iron oxide by combination of the boiler metal in the tube with the bonded oxygen of the boiler water.

Density Ratios

In searching for a reason why higher operating pressures should be particularly effective in developing conditions typical of temperature increment at steam-water interfaces, let us consider the density or number of pounds of saturated steam per cubic foot, and the ratios of the higher pressure densities to that of 400 psi. The values are as follows:

Pressure, psi	Density or lb per cu ft	Ratio of density to density at 400 psi
400	0.894	1.0
1200	2.83	3.05
2000	5.39	6.03
2800	9.92	11.1

These data show the rapid increase of density with pressure. Thus if two bubbles of steam of equal size are generated at an evaporative surface, one at 400 and the other at 2000 psi, at the latter pressure the weight of steam in the bubble is 6.03 times that in the bubble generated at 400 psi. More work has been done to generate the steam bubble at 2000 psi than that at 400 psi. Is the work actually 6.03 times as much?

Btu Ratios

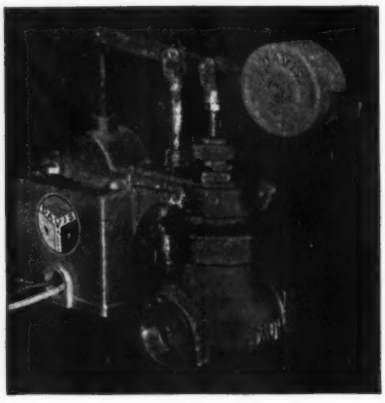
A measure of the work is found in the heat input through the tube to produce the bubble. So, let us next consider the amounts of heat required to develop one cubic foot of saturated steam from water at the same temperature, and the ratios of these amounts to that required at the temperature corresponding to 400 psi. The data are as follows:

Pressure, psi	Heat required to produce 1 cu ft of saturated steam from water at the same temperature, Btu	Ratio of heat required at different pressures to that required at 400 psi
400	693.7	1.0
1200	1704.2	2.46
2000	2463.8	3.55
2800	2654.6	3.83

Thus, in the production of steam bubbles of equal size at 2000 psi and at 400 psi, the heat input through the tube must be 3.55 times as much for the former as for the latter. For bubbles of equal volume, therefore, it is natural that troubles originating at the steam-water interface thereof with the film of water on the boiler tube should be greater the higher the operating pressure. On the one hand, the bubble of higher pressure attains its volume more slowly than the bubble of same volume at 400 psi if at equal rates of heat input, thus making the life period of any such steam-water interface longer. On the other hand, if the rate of heat input is faster at the higher pressure, greater opportunity exists for development of incremental temperature at the steam-water interface, increase of which results in higher concentrations in the concentrating-film boiler water, with correspondingly greater chance of scale deposition, or combination of boiler metal with the bonded oxygen of the boiler water.

Liquid/Saturated Vapor Ratios

There is still another angle to be considered in summing up why the reactions occurring at the steam-water interface are more severe at higher pressures than lower. At the several pressures used in presenting these data,



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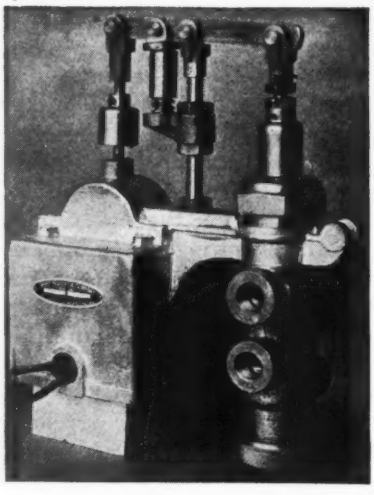
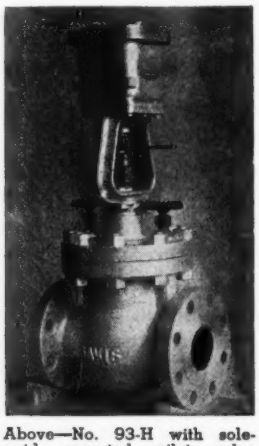
Below—No. 380—a 3 or 4-way pilot valve widely used on air or liquid actuated power cylinders.





Above—No. 93-H with solenoid operated pilot valve and hydraulically actuated main valve built for use on a 400 lb. pressure water main

DAVIS REGULATOR COMPANY

2510 S. Washtenaw Ave. Chicago, Ill.

DAVIS REGULATOR CO.

the densities or pounds per cubic foot of liquid and saturated vapor, and their ratios, are as follows:

Pressure, psi	Density, lb/cu ft Liquid	Saturated vapor	Density ratio, liquid/saturated vapor
400	51.5	0.894	57.6
1200	44.1	2.83	15.6
2000	37.6	5.39	7.0
2800	29.9	9.92	3.0

At 400 psi, the density of the liquid water is 51.5, and of the saturated vapor, 0.894, their ratio being 57.6. At 1200 psi, this ratio has diminished to 15.6. These figures signify a great decrease in the driving force of steam bubbles in promoting circulation, as between 400 psi and 1200 psi. This also means less driving force to separate the bubble from the evaporative surface of a tube, and consequently a longer life period of the steam interfaces at the surface. Another point that arises for the same reason of lesser driving force is that freedom of passage to the steam drum without interposition of any deterrent forces is the more necessary as operating pressures increase.

EQUIPMENT SALES

as reported by equipment manufacturers to the Department of Commerce, Bureau of the Census

Boiler Sales

Stationary Power Boilers

	1944 Water Tube No.	1944 Water Tube Sq Ft*	1943 Water Tube No.	1943 Water Tube Sq Ft*	1944 Fire Tube No.	1944 Fire Tube Sq Ft	1943 Fire Tube No.	1943 Fire Tube Sq Ft
Jan.	36	226,537	11	64,189	24	31,701	16	18,888
Feb.	39	256,942	32	164,800	28	43,341	237	146,834
Mar.	47	229,121	31	147,937	44	53,893	16	24,293
Apr.	80	448,646	95	361,746	50	68,430	21	32,392
May	74	392,347	127	683,052	49	66,722	9	14,106
June	65	286,486	163	679,306	70	92,621	25	41,073
Jan.–June incl.	341	1,840,079	459	2,101,030	265	356,708	324	277,586

* Includes water wall heating surface.

Total steam generating capacity of water tube boilers sold in the period Jan. to June (incl.), 1944, 15,298,000 lb per hr; in 1943, 21,372,000 lb per hr.

Marine Boiler Sales

	1944 Water Tube No.	1944 Water Tube Sq Ft*	1943 Water Tube No.	1943 Water Tube Sq Ft*	1944 Scotch No.	1944 Scotch Sq Ft	1943 Scotch No.	1943 Scotch Sq Ft
Jan.	49	273,879	597	2,185,483	—	—	1	1,080
Feb.	96	507,658	31	102,404	30	9,000	–	—
Mar.	70	226,166	156	430,841	38	9,700	1	2,565
Apr.	44	209,906	19	85,244	48	14,405	2	5,130
May	94	443,130	594	4,985,280	37	11,100	3	6,401
June	193	1,003,435	895	4,241,507	32	13,100	1	2,565
Jan.–June incl.	546	2,664,174	2,292	12,030,759	185	57,305	8	17,741

* Includes water wall heating surface.

Total steam generating capacity of water tube boilers sold in the period Jan. to June (incl.) 1944, 29,486,000 lb per hr; in 1943, 103,277,000 lb per hr.

† Mechanical Stoker Sales

	1944 Water Tube No.	1944 Water Tube Hp	1943 Water Tube No.	1943 Water Tube Hp	1944 Fire Tube No.	1944 Fire Tube Hp	1943 Fire Tube No.	1943 Fire Tube Hp
Jan.	35	13,982	131	46,948	147	20,761	457	31,623
Feb.	35	18,437	106	34,685	156	22,495	575	83,673
Mar.	56	20,128	114	48,367	142	5,660	571	77,729
Apr.	58	21,680	96	32,251	153	21,923	432	64,022
May	54	20,920	96	39,640	222	30,457	414	57,889
June	57	21,055	118	61,415	290	35,592	296	49,760
Jan.–June incl.	295	116,202	661	263,306	1,110	136,888	2,745	364,696

† Capacity over 200 lb of coal per hour.

Combustion Calculations by Graphical Methods— REFINERY AND OIL GAS

This supplements a series of articles by the author in COMBUSTION, over a period from August 1941 through August 1942, in which combustion calculations by graphical methods were given for various solid and gaseous fuels. The present article reviews briefly the methods of processing crudes to produce oil gas and refinery gas, and discusses their composition, characteristics and combustion requirements. Charts are included for readily computing combustion calculations, and a typical example, illustrating use of the charts, is included.

By A. L. NICOLAI

Combustion Engineering Co., Inc.

REFINERY gas and gas oil may both be defined as gaseous fuels composed of uncondensed distillation fractions. Aside from differences in composition, refinery gas is distinguished commercially by being a by-product, whereas oil gas is classed as a main product of distillation.

In order better to understand the nature of oil and refinery gases, the methods of treating crudes are briefly reviewed.

Petroleum, much the same as coal, is the primary source of a variety of solid, liquid and gaseous products, which are used as fuels for the production of steam, and for other purposes. Among the solid fuels, derived from this source, are the heavy tars, pitches and cokes which are collected at the bottom of stills; the liquid products comprise gasoline, kerosene, gas oils and various grades of fuel oils, as well as semi-fluid sludges left over from refinery operations. Finally, petroleum is the source of a variety of gaseous fuels, some of which are purposely manufactured for sale, such as oil gas and carburetted water gas, and others that are considered in the nature of waste products and are known as refinery gases.

There are two basically different ways of processing crudes. The first and older is distillation; the second and more recent is cracking. Frequently, in modern refinery practice, both these methods are combined into the same or successive operations.

Distillation

In a typical continuous distillation process, such as is outlined in the sketch, Fig. 1, the crude oil is first pre-

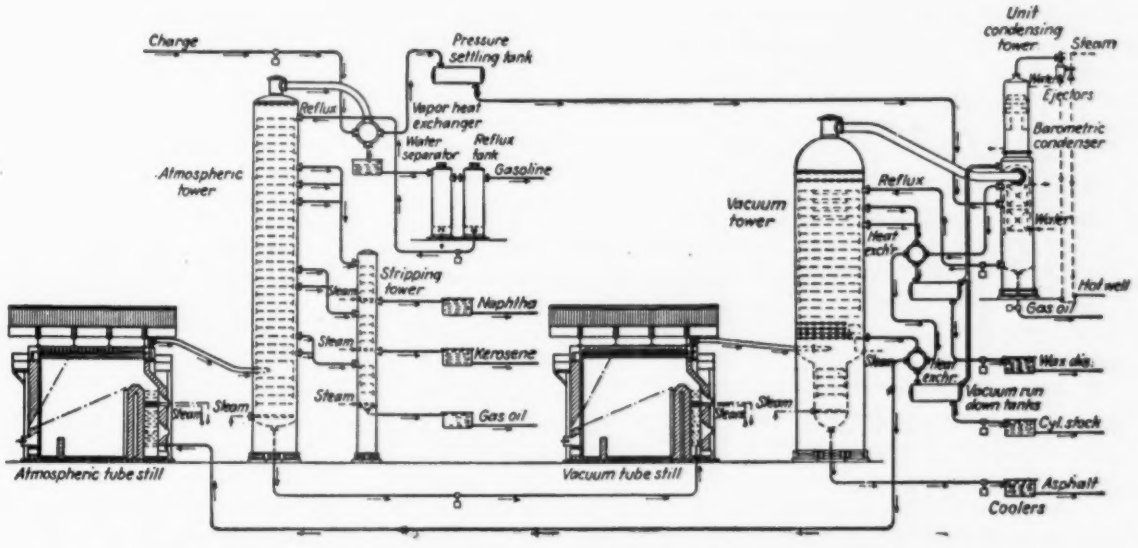


Fig. 1—Diagram of a two-stage atmospheric and vacuum distillation unit

From Carey Ind. & Eng. Chem., 27, 795 (1935)

heated in a tube still to a temperature of about 600 F. The charge is then sent to a fractionating tower, or column, where it is flashed at atmospheric pressure and separated into its various components according to their specific gravity. At the top of the column the gasoline vapors are taken off at about 225 F. Below the top comes the removal of various "side streams": first, heavy naphtha at 330 F, next, kerosene at 425 F, then, gas oil at 530 F. At the bottom of the tower the liquid residuum is drawn off and led to another still, where it is heated again to about 780 F and discharged into a second column, which is maintained at an absolute pressure of 2 to 3 in. Hg. From the top of this tower comes additional gas oil vapors at 375 F, while the side streams consist of wax distillate at 500 F and lubricating stock at 690 F. Asphalt residuum is collected at the bottom at a temperature of 710 F.

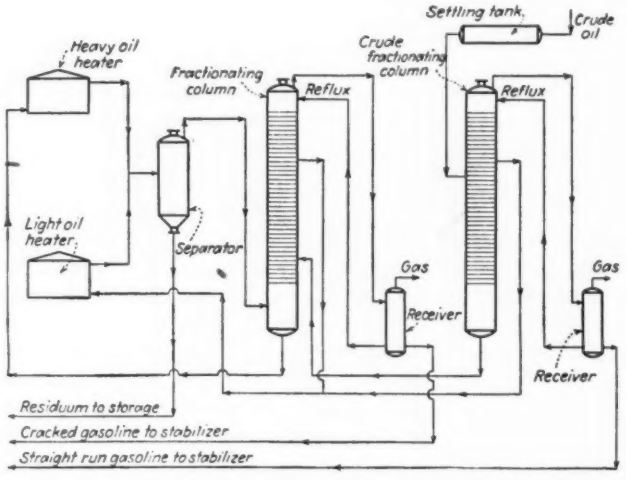


Fig. 2—Elements of flow diagram for a cracking process
From Chemical Technology of Petroleum by Gruse and Stevens

In addition to distillation being carried out at atmospheric pressure or under vacuum, it may take place in the presence of steam or other inactive gas. Both vacuum and steam distillation permit fractionation at lower temperature.

After primary distillation of the crude, it sometimes becomes desirable to remove from the gasoline the lighter hydrocarbons, such as propane and butane. This secondary operation, known as stabilization, is performed by heating the charge to 300 F and sending it for separation to a fractionating tower, or stabilizer, kept at a pressure of 50 to 70 psi.

In order to remove objectionable asphaltic materials or substances that oxidize on exposure, the distillates are often further purified by using chemical reagents, such as sulphuric acid, aluminum chloride or zinc chloride. Such refining treatment may add obnoxious sulphur compounds, which make the distillation products "sour." By agitating them with alkaline sodium plumbite (doctor solution), calcium hypochlorite, lead sulphide or other chemical, the distillates are subsequently "sweetened."

Cracking

Cracking may be defined as the thermal decomposition of petroleum. In a typical cracking process, as indicated by Fig. 2, the stream of crude oil is heated in tube coils to a temperature of 850 to 1000 F and discharged, under a pressure of perhaps 750 psi, first into separators which eliminate the tar and heavy oil, and then into a fractionating tower. The oil is pumped through the heater fast enough to prevent its decomposition before it has left the tubes. The actual temperature and pressure employed depend on the character of the crude and also on the end products desired.

There are four principal factors that influence both the yield and the composition of gases formed in a cracking operation; these are: (1) the operating temperature, (2) the operating pressure, (3) the character of the charge, and (4) the time involved in the operation.

Temperature is the most important single element because it has the greatest influence on the character of the ensuing cracked products. This is clearly illustrated by Fig. 3, from which it is seen that in the cracking of propane alone, the hydrocarbons and the hydrogen evolved vary considerably in amount depending on the temperature of the enclosing vessel.

In the cracking of petroleum, which is a homogeneous mixture of many hydrocarbon compounds, slow decomposition begins at about 600 F, with the evolution of products of a lower boiling point than the original oil proceeding up to 1100 F. From 1100 F to 1300 F gas oil is yielded; at approximately 1650 F aromatic hydrocarbons come off, and above 1850 F the chief products consist of methane, hydrogen and carbon. Quite generally, an increase in temperature results in a higher gas evolution.

Pressure is not as much of a controlling factor as temperature, and, in cracking processes, it is generally kept above 200 psi. An increase in pressure reduces the amount of gas, lowers the proportion of aromatics and hydrogen in it, and raises the unsaturated hydrocarbon content.

The origin and kind of charge has a definite effect on both the composition and the quantity of the refinery gas formed. Thus, whereas a North Texas kerosene distillate only results in a yield of 69 cu ft of gas per barrel of oil charged, the gas produced by cracking a Mid-Continent gas oil is as much as 303 cu ft per barrel.

An increase in the time during which cracking takes place always raises the quantity of gas produced, augmenting, at the same time, the fraction of saturated hydrocarbons in the gas.

It is noteworthy that a cracking process invariably generates a greater proportion of gas than straight distillation, the cracked gas averaging 10 per cent of the material handled.

Refinery Gas and Oil Gas

As a fuel, refinery gas is withdrawn from whatever point in the refining system it is found economical to do so. It may come from raw gasoline tanks, from stabilizers, from cracking stills, from adsorbers used in purifying operations, etc. Likewise, depending on the process and the point of origin in the system, the fuel gas may be at, below or above atmospheric pressure; if it comes from a condenser, it may be at ordinary room temperature, but its temperature may be much higher if taken directly from a cracking still or fractionating tower. Often, refinery gases from various sources in the plant are blended together before being burned.

Oil gas deserves special mention because, being specifically manufactured for commercial purposes, rather than a

CHARACTERISTICS OF TYPICAL REFINERY AND OIL GASES

Per Cent by Volume												Density,	Heat Value Btu/Cu Ft		Heat Value Btu/Lb		Atm. Air at Zero Excess Air,	CO_2 at Zero Excess Air,
O_2	N_2	CO_2	CO	H_2	H_2S	CH_4	C_2H_6	C_3H_8	C_4H_{10}*	C_5H_{12}†	C_nH_m‡	Lb/Cu Ft	High	Low	High	Low	Lb/10^6 Btu	Per Cent
...	...	...	...	...	2.18	41.62	20.91	19.72	9.05	6.52	...	0.08449	1809	1657	21,400	19,600	736	13.2
...	...	...	...	...	...	4.30	82.70	13.00	...	...	...	0.08174	1781	1629	21,800	19,950	734	13.3
...	...	...	...	...	...	92.10	1.90	4.50	1.30	0.20	...	0.04799	1104	1000	23,050	20,850	730	12.1
...	...	...	...	...	...	5.0	12.0	30.0	34.0	19.0	...	0.13290	2814	2597	21,150	19,550	738	13.9
...	...	3.3	1.5	5.6	...	30.9	19.8	38.1	0.6	...	0.2	0.07869	1625	1489	20,650	18,920	732	13.4
2.3	8.7	...	...	...	...	30.3	13.4	19.1	14.7	1.8	9.7	0.08977	1759	1619	19,600	18,030	726	13.6
0.9	8.4	2.2	14.3	50.9	...	15.9	5.0	...	...	...	2.4	0.03632	507	454	13,970	12,500	652	12.6
0.1	2.7	1.0	6.8	59.2	...	25.4	...	...	...	...	4.8	0.02780	572	511	20,550	18,380	666	10.7

* Includes both iso-C_4H_{10} and n-C_4H_{10}.
† Includes all percentages of saturated hydrocarbon series heavier than C_5H_{12}, as well as both iso-C_5H_{12} and n-C_5H_{12}.
‡ Includes all illuminants.

byproduct, its final composition is governed by the heat value that is standard for the locality where it is sold. This heat value is customarily set at about 535 Btu per standard cubic foot.

Oil gas is produced by spraying oil into a retort heated to about 1300 F, causing thermal decomposition to occur. Cracking of the oil is then completed by passing the gas through a second retort, which converts the unstable hydrocarbons of low molecular weight into permanently gaseous hydrocarbons. In this manner about 85 per cent of the oil is recovered as gas.

The range in composition for both refinery and oil gases is shown by the accompanying table. Refinery gas is predominantly made up of saturated gases of low boiling point, such as, methane (CH_4), ethane (C_2H_6), propane (C_3H_8), butane (C_4H_{10}), and pentane (C_5H_{12}) with small amounts of illuminants. Minor quantities of carbon dioxide (CO_2), carbon monoxide (CO), and hydrogen (H_2) may also be present with oxygen (O_2) and nitrogen (N_2) introduced to lower the hydrocarbon vapor pressure, in some cracking processes. If the original crudes contained sulphur, the ensuing gases include hydrogen sulphide (H_2S) unless the sulphur compounds have been removed by purifying operations. In the table, here included, the last two analyses represent oil gas, whereas the others are representative of refinery gas. It may be noticed that the hydrogen content of oil gas is higher than that of refinery gas, as is also that of the carbon monoxide.

DENSITY—In a previously published article on blast furnace gas[1] a method was outlined for calculating the density of a gaseous fuel, given its analysis by volume. The same method can be used to find the density of refinery gas, or oil gas, either at 62 F or at a higher temperature.

No correction for gas pressure other than the standard 30 in. Hg is required in the calculation of density, because invariably the fuel is burned in a furnace which is at atmospheric pressure. The table indicates that the density of gas oil is considerably lower than that of refinery gas.

HEATING VALUE—The heating value in Btu per cu ft of the fuel being discussed is computed as set forth in the article on natural gas,[2] with appropriate correcting factors for temperature and moisture as derived for blast-furnace gas. The method described in the foregoing articles can be applied to finding equally the high or the low calorific value.

The Btu per pound is the ratio of Btu per cu ft and the density as calculated in the manner just recommended.

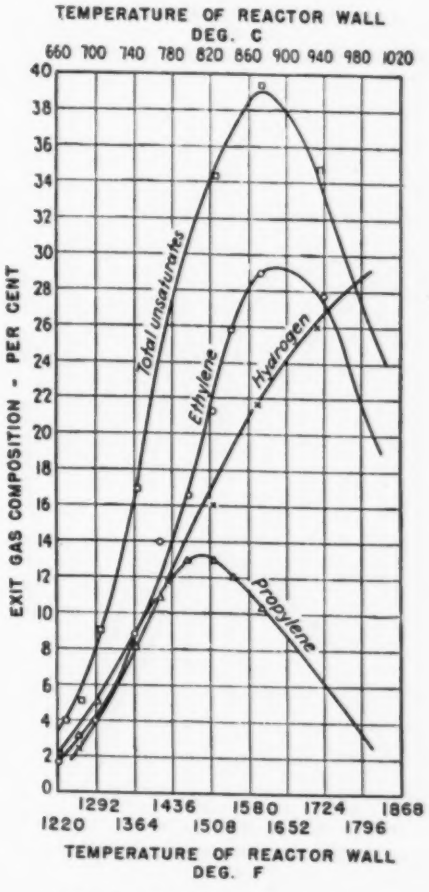


Fig. 3—Cracking of propane
From Frolich and Wiezevich, Ind. & Eng. Chem., 27, 1055 (1935)

Although there is no doubt that some refinery gases contain little or no moisture, others are saturated with it. By assuming them to be saturated with moisture at 62 F, as was done for the table, the resulting density and heat value are deemed "conservative" from the standpoint of the designing engineer, since both the Btu per cu ft and the density thus arrived at are lower than the corresponding dry values.

FUEL IN PRODUCTS, F—With the Btu per pound (HHV) already determined, it is only necessary to refer to the chart published in the August 1941 issue of COMBUSTION, for the value of F, which may also be calculated directly by slide rule from:

$$F = \frac{10^6}{HHV} \qquad (24)$$

[1] COMBUSTION, December 1941.
[2] COMBUSTION, February 1942.

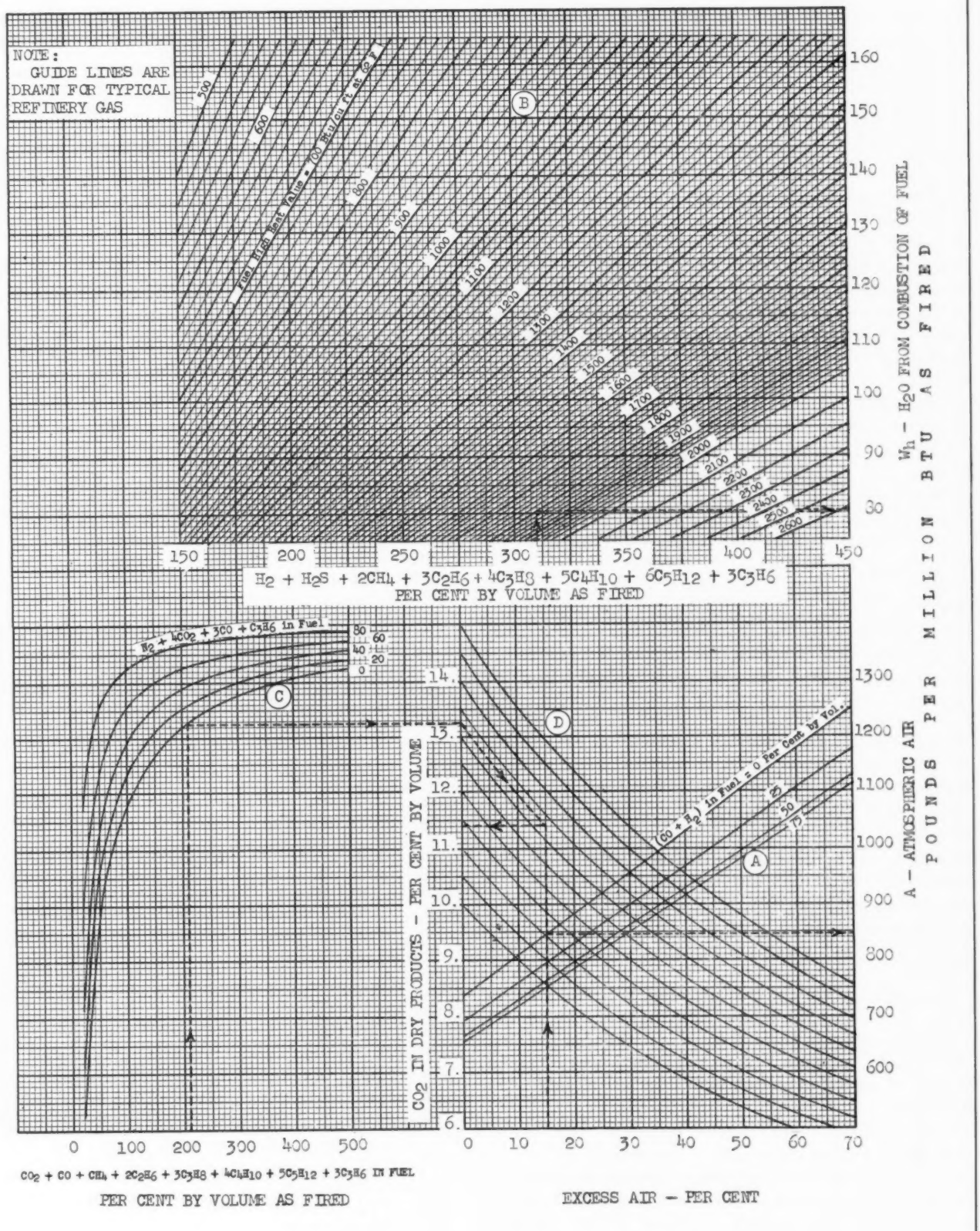


Fig. 4—Variation of theoretical air with CO + H_2

ATMOSPHERIC AIR, A—The air required for combustion may be conveniently read from lines A of Fig. 5 for amounts of excess air up to 70 per cent of the theoretical requirements. Due to the relatively large percentages of carbon monoxide and hydrogen present in some of the oil gases, the magnitude of A in the table here presented varies from 652 to 738 lb per million Btu. The correlation of A at zero excess air with the term $(CO + H_2)$ is brought out by Fig. 4. The average line drawn through the calculated points on this figure was used as the basis for spacing lines A of Fig. 5.

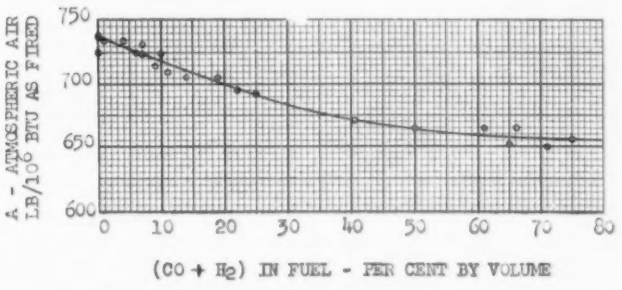


Fig. 5—Chart for refinery gas and oil gas

The atmospheric air as taken from Fig. 5 can be corrected for temperature and moisture content other than saturation at 62 F by employing equation (13) of the article on blast furnace gas.

TOTAL PRODUCTS, P—Knowing A and F, the total wet products formed by combustion of refinery or oil gas can be easily computed, in pounds per million Btu fired, by the addition $P = F + CA$, where C is the correction factor for combustible loss due to imperfect combustion.

MOISTURE FROM FUEL, W_f—The total amount of moisture in the products of combustion, W_f, which is derived from the fuel itself, is the summation of the entrained moisture W_e, the water vapor held by the gas W_s, and the water produced by burning hydrogen, or hydrogen compounds, making up the fuel.

Unless the refinery gas has undergone a scrubbing or washing operation to remove objectionable elements from the distillate, it hardly contains any entrained moisture. Water vapor, however, may be present in the gas not only because of the purifying treatment, but due to water introduced into the system with the crude oil, or because of steam employed in the distillation process. If the gas is saturated with moisture at any other temperature than 62 F, W_s can be determined from the chart given in the article on natural gas.

The water which is formed by combustion, W_h, can be read from lines B of Fig. 5, which are a plot of the expression

$$W_h = \frac{46{,}700\,(H_2 + H_2S + 2CH_4 + 3C_2H_6 + 4C_3H_8 + 5C_4H_{10} + 6C_5H_{12} + 3C_3H_6)}{\text{Btu per cu ft at 62 F and 30 in. Hg}} \quad (25)$$

When, for more accuracy, it is required to correct W_h for the effect of temperature and moisture content other than as assumed by standard conditions, equation (15) of the article on blast-furnace gas, previously mentioned, can be utilized.

PER CENT CO_2 IN PRODUCTS—For zero excess air, the CO_2 in the dry products of combustion is found with the aid of curves C, Fig. 5. These curves were drawn from the approximate equation:

$$\text{Per cent } CO_2 \text{ (at zero excess air)} = \frac{100}{6.64 + \dfrac{188 - 1.88(N_2 + 4CO_2 + 3CO + C_3H_6)}{CO_2 + CO + CH_4 + 2C_2H_6 + 3C_3H_8 + 4C_4H_{10} + 5C_5H_{12} + 3C_3H_6}} \quad (26)$$

The guide lines D of Fig. 5 make it possible to obtain the percentage of CO_2 in the products for an excess air value up to 70 per cent.

EXAMPLE

Assume a refinery gas to have the typical analysis in the first line of the table to be fired at a temperature of 62 F with 15 per cent excess air. Then

1. FUEL, F. With a fuel high heat value of 21,400 Btu per lb, refer to the August 1941 article in COMBUSTION on "Combustion Calculations by Graphical Methods" and from Fig. 1 obtain $F = 47$ lb per million Btu.

2. ATMOSPHERIC AIR, A. On lines A, Fig. 5, for 15 per cent excess air and $(CO + H_2) = 0$, read $A = 847$ lb per million Btu.

3. UNBURNED COMBUSTIBLE. When burning refinery gas in boiler furnaces, it is customary to assume that there is no unburned combustible loss, so that in equations (3) and 4 of the August 1941 article just mentioned $C = 1$.

4. TOTAL PRODUCTS, P. Using equation (4),[1] $P = F + CA = 47 + 1 \times 847 = 894$ lb per million Btu.

5. MOISTURE IN AIR, W_a. This item is calculated from equation (5),[1] $W_a = 0.013A = 0.013 \times 847 = 11$ lb per million Btu.

6. MOISTURE FROM FUEL, W_f. The moisture content of refinery gas itself is generally negligible. The water formed by its combustion is taken from curves B, Fig. 5. For a high heat value of 1809 Btu per cu ft and $H_2S + 2CH_4 + 3C_2H_6 + 4C_3H_8 + 5C_4H_{10} + 6C_5H_{12} = 2.18 + 83.24 + 62.73 + 78.88 + 45.25 + 39.12 = 311.40$ per cent by volume, $W_f = W_h = 80$ lb per million Btu.

7. DRY GAS, P_d. From equation (7),[1] $P_d = P - (W_a + W_f) = 894 - (11 + 80) = 803$ lb per million Btu.

8. PER CENT CO_2 IN PRODUCTS. The CO_2 at zero excess air is determined first. From curves C of Fig. 5, for $CH_4 + 2C_2H_6 + 3C_3H_8 + 4C_4H_{10} + 5C_5H_{12} = 41.62 + 41.82 + 59.16 + 36.20 + 32.60 = 211.40$ per cent by volume, obtain 13.2 per cent CO_2. With curves D as guide lines and 15 per cent excess air, then, read $CO_2 = 11.4$ per cent.

[1] COMBUSTION, August 1941.

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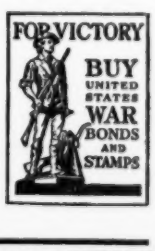

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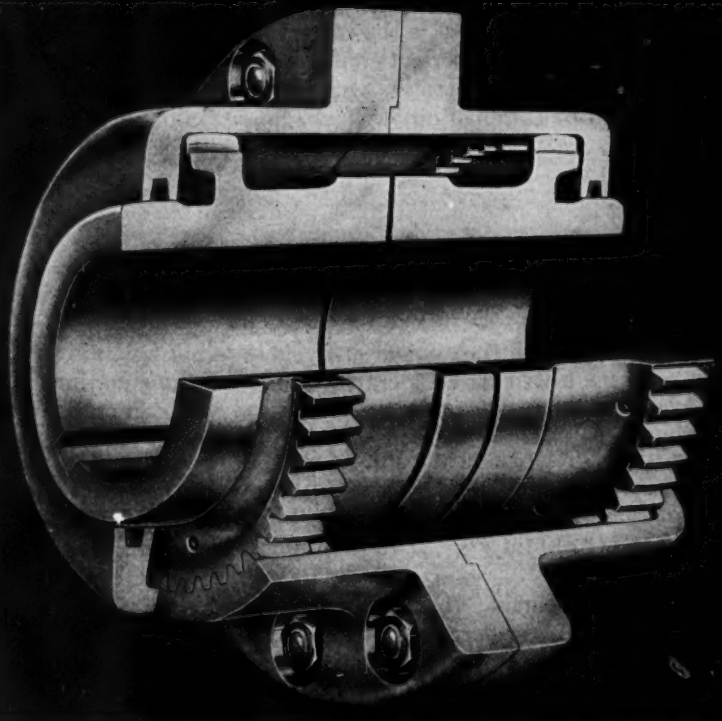

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Balance of Radiation in Employing Optical Pyrometry

By MAX JAKOB*

ENGINEERS, confident that what they measure with their tapes and rulers are true lengths, or what they read at reliable amperemeters are true electrical currents, have extended this trust to all kinds of thermometric devices, particularly so because they learned that the indications of calibrated mercury-in-glass thermometers, thermocouples, etc., have a high degree of accuracy. Only reluctantly do they take cognizance of the fact that exact reading of a good thermometric instrument does not help much if the influence of arrangement and environment upon the result is not carefully considered and corrected.

It is gratifying that Messrs. Reid and Corey recently analyzed the errors in temperature measurement by radiometric methods in a thorough paper in this magazine,[1] and I am sure that many readers will have been surprised, if not shocked, by learning that in certain practical cases errors of 1000 F and more may occur if the right type of pyrometers is not used. The present discussion is written to supplement one item of the quoted paper. It is shown there that the total radiation pyrometer requires much smaller corrections than the optical pyrometer when the temperature of a relatively cold surface in a hot environment is to be measured; for instance, the temperature of superheater tubes in the furnace of a boiler. Moreover, it is required that the temperature of the observed surface can be estimated approximately in order to find the necessary correction.

This estimate, however, can be superseded by a measurement of the inner-surface temperature of the furnace as will be understood from the following balance of radiation which is based on Wien's and Kirchhoff's laws:

$$J_\lambda = c_1\lambda^{-5}e^{-\frac{c_2}{\lambda T_a}} = c_1\epsilon_\lambda\lambda^{-5}e^{-\frac{c_2}{\lambda T}} + c_1\epsilon_{e\lambda}(1-\epsilon_\lambda)\lambda^{-5}e^{-\frac{c_2}{\lambda T_e}} \quad (1)$$

or

$$\epsilon_\lambda e^{-\frac{c_2}{\lambda T}} = e^{-\frac{c_2}{\lambda T_a}} - \epsilon_{e\lambda}(1-\epsilon_\lambda)e^{-\frac{c_2}{\lambda T_e}} \quad (2)$$

In these equations,

J_λ is the intensity of the radiation at wave length $\lambda = 0.65\ (10^{-4})$ cm which enters the pyrometer.

c_1 and c_2 are the constants of Wien's law of radiation.

T_a is the apparent absolute temperature, i.e., the temperature of a black body radiating at the same intensity.

The author shows by several examples how an estimate of the emissivity of the observed surface can be missed and that only a part of what is often termed the error of a pyrometer deserves this designation, whereas the greater part may be considered as a deviation, due to the principle of the instrument and is correctable.

T_e is the absolute temperature of the environment, for instance, of the inner furnace surface having the emissivity $\epsilon_{e\lambda}$.

T is the true absolute temperature of the observed surface having the emissivity ϵ_λ.

Equation (2) yields T from T_a and T_e, as observed by the pyrometer, independent of whether the environment of the observed surface is warmer or colder than this surface. Compared with the corresponding heat balance for total radiation which is based on Stefan-Boltzmann's and Kirchhoff's law, it has a certain advantage in so far as gas radiation, if any, does not influence the result because λ is far from the range of the long wave bands of carbon dioxide and water vapor. The indication of a total radiation pyrometer, on the other hand, requires a correction for the absorption of the radiation by the furnace gas, particularly if the observed surface is relatively cold and well reflecting. However, the measurement by an optical pyrometer has other and stronger handicaps as has been shown in the quoted paper.

The limitations of the optical pyrometry will be made clear by some numerical examples of the balance of monochromatic radiation. In these calculations it will not be charged as an error or failure of the optical pyrometer if the indicated temperature, T_a, is different from the true temperature, T, of the observed surface because according to equations (1) and (2), this generally cannot be avoided. The instrument will rather be said to fail when T cannot be calculated satisfactorily from these equations or when unavoidable deviations in the estimate of the emissivity ϵ_λ make the calculated value of T too uncertain.

For convenience, t_a, t_e and t will be given in degrees Fahrenheit (F). In equation (1) and (2), however, the corresponding temperatures T_a, T_e and T are expressed in degrees Kelvin (K). The absolute temperature of melting ice is assumed to be 273.2 C, and the second constant of the law of radiation $c_2 = 1.4360$ cm K. Since the right side of equation (2) is a difference of two terms, which in some cases may be almost equal, five-place logarithms have been used for these calculations.

Finally, it may be mentioned that in all examples $\epsilon_{e\lambda} = 1$ has been assumed

Examples

EXAMPLE 1

A surface of emissivity $\epsilon_\lambda = 0.99$ and true temperature $t = 1000$ F is viewed in a furnace of wall temperature $t_e = 2700$ F. From equation (1)

$$e^{15-\frac{c_2}{\lambda T_a}} = \epsilon_\lambda e^{15-\frac{c_2}{\lambda T}} + (1-\epsilon_\lambda)e^{15-\frac{c_2}{\lambda T_e}} \quad (3)$$

The value 15 in all exponents is added for convenience. Substituting the values of T and T_e

$$e^{15-\frac{c_2}{\lambda T_a}} = 0.000004782 + 0.111844 = 0.111849 \quad (4)$$

which yields

$$T_a = 1285.1 \text{ K or } t_a = 1853.4 \text{ F}$$

Conversely, when $t_a = 1853.4$ F and $t_e = 2700$ F are observed by the pyrometer, equation (3) should lead to the true temperature $t = 1000$ F. However, the term with T in equations (3) and (4) is so small, that the numerical calculation of T is practically impossible in this case. The reason, of course, is that the emission of the surface is only about $^4/_{100,000}$ of the reflection of the furnace radiation by that surface.

EXAMPLE 2

$\epsilon_\lambda = 0.50$; $t = 1000$ F; $t_e = 2700$ F

Using equation (3)

$$e^{15-\frac{c_2}{\lambda T_a}} = 0.0000024152 + 5.5922 = 5.59220$$

and

$$T_a = 1667 \text{ K or } t_a = 2541.4 \text{ F}$$

Again the term containing T is so small that a measurement of the true temperature by this method is impossible.

EXAMPLE 3

$\epsilon_\lambda = 0.99$; $t = 2000$ F; $t_e = 2700$ F

From equation (3)

$$e^{15-\frac{c_2}{\lambda T_a}} = 0.30867 + 0.111844 = 0.420514$$

and

$$T_a = 1395.1 \text{ K or } 2051.4 \text{ F}$$

In this case the emission of the observed surface prevails, and its true temperature

* Consultant in Heat Research, Armour Research Foundation; Research Professor of Mechanical Engineering, Illinois Institute of Technology; Nonresident Research Professor of Heat Transfer, Purdue University.

[1] W. T. Reid and R. C. Corey, COMBUSTION, Vol. 15, No. 8, p. 30, 1944.

can easily be calculated provided that the emissivity ϵ_λ is exactly known.

Assume now that the emissivity was erroneously estimated as $\epsilon_\lambda = 0.98$ instead of the true value of 0.99. The reading T_a on the pyrometer is not changed by this error. Equation (2), however, yields $T = 1334.1$ K or $t = 1942.0$ F, that is, 58 F less than the actual temperature. Since it is almost impossible to say whether the emissivity of a nearly black surface is 0.99 or 0.98, the measurement of a surface temperature of actually 2000 F will be uncertain by at least 50 or 100 deg F.

EXAMPLE 4

$\epsilon_\lambda = 0.50$; $t = 2000$ F; $t_e = 2700$ F

From equation (3)

$$e^{15} - \frac{c_2}{\lambda T_a} = 0.155895 + 5.5922 = 5.748095$$

and

$$T_a = 1667.2 \text{ K or } t_a = 2541.2 \text{ F}$$

Although the emission of the observed surface is less than 3 per cent of the reflected radiation, t can be fairly well calculated from the observed values of t_a and t_e.

In estimating ϵ_λ an error of ± 0.05 is not unlikely. If, in the present case, ϵ_λ had been guessed to be between 0.45 and 0.486, the right-hand side of equation (2) would take negative values. This is impossible because the left-hand side can only be positive. Assuming ϵ_λ between 0.486 and 0.50, yields t between ∞ and 2000 F, respectively. So, the optical pyrometer fails if ϵ_λ is underestimated just a little.

If, on the other hand, $\epsilon_\lambda = 0.55$ was assumed, the calculation would lead to $T = 1499.1$ K or $t = 2238.6$ F instead of 2000 F which is still unsatisfactory.

EXAMPLE 5

Using the balance of total radiation, as given in the quoted paper, a total radiation pyrometer would indicate $t_a = 2413.4$ F if the total emissivity $\epsilon = 0.50$, $t = 2000$ F and $t_e = 2700$ F. Conversely, the balance equation yields the true value $t = 2000$ F if $t_a = 2431.4$ F and $t_b = 2700$ F are observed. An erroneous estimate of $\epsilon = 0.55$ leads to $t = 2091.0$ F, and an estimate of $\epsilon = 0.45$ leads to $t = 1872.7$ F. So, using a total radiation instrument, an error of ± 0.05 in estimating ϵ means an error of about ± 100 deg F in the measurement of the true temperature t. This is bad enough, but much better than the measurement with an optical pyrometer under the same conditions (see Example 4).

Conclusions

1. The difference between the true temperature of a surface and the apparent temperature indicated by a pyrometer should not be called an error of the thermometry. The error is only that part of the difference which cannot be properly corrected, due to environmental influences or erroneous estimates of the emissivity of the surface.

2. The optical pyrometry of a surface at relatively low temperature in a surrounding of high temperature fails, as shown already in the previously mentioned article of Reid and Corey.

3. The true temperature of a surface in a not very much hotter environment can be found by means of a balance of monochromatic radiation without estimating the surface temperature, if the temperature of environment is also measured by optical pyrometry.

4. However, also in this case the optical pyrometer is strongly influenced by unavoidable errors in estimating the emissivity of the surface.

5. Only if the temperature of the observed surface is not much below the temperature of environment and the emissivity is well known, the optical pyrometer can be employed. Therefore, more and better experimental data on emissivities than are now available would enlarge the range in which this instrument can be used.

6. As has already been shown in the paper of Reid and Corey, the total radiation pyrometer is more suitable than the optical pyrometer if the environment is much warmer than the observed surface.

7. The reading of a total radiation pyrometer should be corrected for gas radiation, if any, whereas the optical pyrometer is free of such correction.

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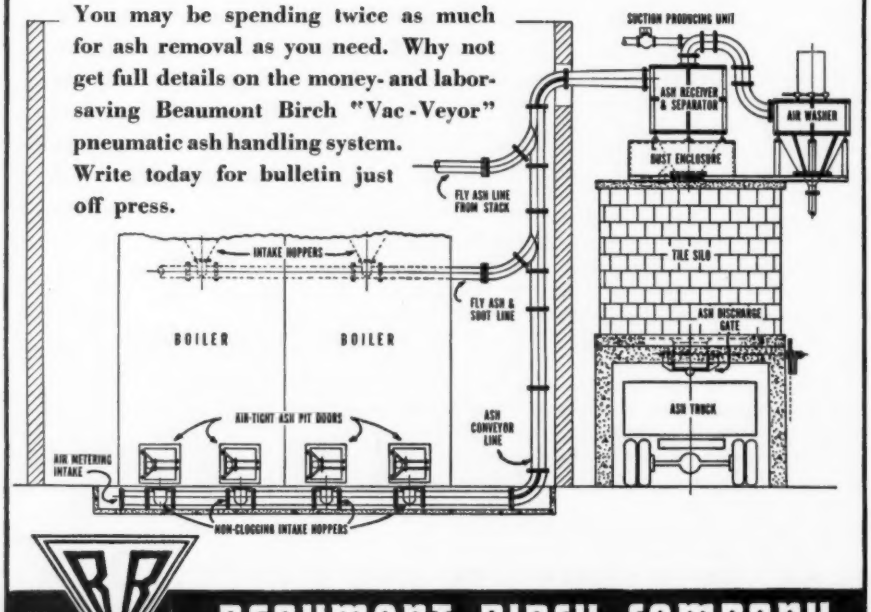

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Power Demands and Energy Requirements

Peak demands of the principal electric utility systems of the country for June 1944 aggregated 35,845,147 kw, an increase of approximately 535,000 kw over the preceding month and a gain of 6.4 per cent over June 1943. Preliminary figures on electric energy requirements, as compiled by the Federal Power Commission, indicate a total of 18,331,605,000 kwhr, down about 325,000,000 kwhr from May which had one additional day, but an increase of 4.2 per cent over June of last year.

Percentage increases of energy requirements and peak demands by regions for June 1944 over those for the same month of the previous year are shown below:

PERCENTAGE INCREASE—JUNE 1944 OVER JUNE 1943

Region	Energy	Demand
Northeast	−1.9	1.7
East Central	8.1	8.8
Southeast	2.0	3.8
North Central	4.3	7.0
South Central	12.0	12.3
West Central	8.6	8.8
Northwest	7.5	9.1
Southwest	7.8	12.5
U. S. Total	4.2	6.4

The latest available totals of Class I system estimates of the year's energy requirements and December peak demands for 1944 are 227,561,081,000 kwhr and 38,495,243 kw.

Generating capacity (nameplate rating) for these same systems, including scheduled additions, is expected to total 45,924,423 kw at the end of December 1944.

Prevention of Corrosion in Steam-Heating Systems by Cyclohexylamine

CORROSION of sections of piping used in steam-heating systems is frequently regarded as unavoidable, and periodic replacement is provided. Surfaces exposed to newly condensed steam appear to be especially vulnerable to attack. As an added nuisance, solid products of the corrosion tend to accumulate and plug return lines.

The trouble is ascribed in the main to carbon dioxide and oxygen dissolved in the condensate. When oxygen is the principal factor, the corrosion usually is characterized by pitting. Carbon dioxide tends to cause an acidic condensate which dissolves the metal more uniformly and produces the familiar failure at threaded areas where the piping is relatively thin, and where high stress may tend to accelerate the attack.

Carbon dioxide enters the system with the feedwater, generally in a combined form such as carbonates and bicarbonates. Oxygen enters both with the raw feedwater and as air leaking into lines under partial vacuum. The larger central-heating plants have sought to reduce corrosion by eliminating these gases as much as possible. A smaller plant ordinarily lacks the equipment and technical supervision required for this purpose.

In some instances sufficient oil may be injected into the steam to coat the piping and thus help to separate metal from condensate, but such measures are not always successful where the condensed steam is returned to the boilers. Volatile alkaline substances also have been added to the boiler water to neutralize the carbonic acid in the steam and provide an alkaline condensate. This method would prevent acid corrosion. Oxygen corrosion may be minimized, but not necessarily entirely prevented by alkaline conditions. Use of ammonia as the alkalizing agent apparently cannot be followed in most cases because this substance tends to corrode brass and copper valves and fittings.

Amine Treatments

On the other hand, it is claimed that certain amines are both useful and practical inhibitors of return-line corrosion. These chemicals are members of a class of compounds in which one or more hydrogen atoms of the ammonia molecule is substituted by an organic group. Some of the simpler types are soluble in water and volatilize from steaming alkaline boiler waters. Since many of the amines are more caustic than ammonia, condensed steam in which they were present would have a greater tendency to be alkaline. They are also said to be much less corrosive to copper and its alloys than ammonia.

Severe corrosion experienced at Government-operated steam-heating plants, especially those at army camps, has led to the use of amine treatment at many locations. The amine used practically exclusively up to the present time has been cyclohexylamine. Corrosion has been conspicuously reduced; but in many cases the cost of the treatment was found to be excessive.

Therefore, an investigation of the process was made under the direction of the Bureau of Mines and is reported by **A. A. Berk** in Bulletin R.I. 3754 which has just been released. Mr. Berk's conclusions are as follows:

Corrosion of steam heating systems is due principally to carbon dioxide, which acidifies the condensate. One method of preventing corrosion is to introduce sufficient amine into the steam to neutralize the acidity. The use of cyclohexylamine for this purpose has been studied both in the laboratory and in an operating system.

The amine is very volatile from boiling water, so much so that it appears to leave the boiler with the steam practically as soon as it enters with the feedwater. To maintain an alkaline condition in the condensate at traps and heaters, frequent and preferably continuous additions of amine must be made to the system.

In a system that is amine-treated all of the carbon dioxide in the steam tends to be fixed in the condensate and returned to the boiler for recirculation. Condensate which is not returned to the boiler is important, not because of its amine content but because it must be replaced by raw water, the source of additional carbon dioxide. For this reason, loss of water as blowdown is almost as expensive in terms of makeup amine as loss of condensate, although the former contains no cyclohexylamine.

A deaerating heater, operated at temperatures b low 212 F, volatilized a large percentage of the amine recirculated with the condensate. The quantity of carbon dioxide vented simultaneously was relatively small. Above 212 F, the increased loss of amine was small, but much more carbon dioxide was removed. Requirements of makeup amine for the cyclohexylamine treatment would appear to be least if the heater were operated at as high a temperature as possible. This may mean no recirculation of amine to the boiler, but at the same time there would be a minimum of carbon dioxide in the steam.

Cyclohexylamine treatment has helped reduce return-condensate corrosion in steam-heating systems. This result cannot be attributed entirely to its alkalinity, for in many instances the quantity of amine in the steam was small compared with the carbon-dioxide content. It is probable that the amine can inhibit corrosion in the manner peculiar to the nitrogenous bases to which it is related.

All of the defects in the use of cyclohexylamine in steam systems are due to its excessive volatility. This disadvantage is not unsurmountable, since it can be overcome through determining a less-volatile amine of the same desirable properties. Amine treatment has been shown to be useful in steam systems where return-line corrosion is a serious problem.

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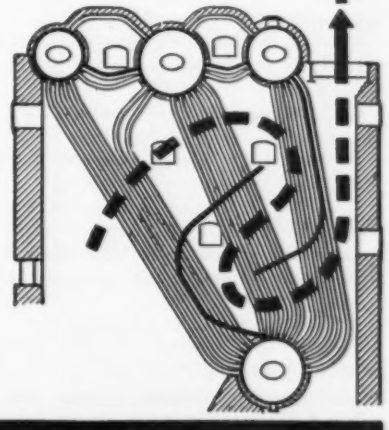


THE ENGINEER CO.
Enco 75 West St. New York, N. Y.

Guide for Checking Fuel Waste

FOLLOWING is a summary of a number of individual sheets, termed "Waste Chaser's Quiz," prepared by the American Boiler & Affiliated Industries for distribution under the National Fuel Efficiency Program which is now being conducted with the cooperation of the U. S. Bureau of Mines. The purpose is to aid in checking conditions and methods of operating steam-generating equipment, to the end that needless waste in fuel may be eliminated. Obviously, the questions and answers are necessarily general in character and cannot cover special conditions.

Separate sheets have been issued for hand-fired, stoker-fired (underfeed, traveling-grate and spreader stokers), oil- and gas-fired, and pulverized-coal-fired boilers, about half of the questions and answers being basic to all types; these are:

1. Do you have any air leaks into the boiler setting?

Leaks may be detected by holding a candle flame close to suspected points of leakage such as cracks in the brickwork or around headers, drums, peepholes, shells, doors or soot blowers. You must have complete control of the air entering the unit.

2. Are the fire sides of your tubes and gas passages clean?

Clean heating surfaces save fuel by giving better heat transfer and lower stack temperatures. A fuel saving of approximately 1 per cent can be made for each 35 deg reduction in stack temperature attained in this way. Keep all gas passages through the boilers free from soot and fly-ash accumulations.

3. Are there holes or leaks in the baffles?

Leaky baffles waste fuel by permitting the gases to short-circuit the heating surface. Repair or renew such baffles.

4. Is the water side of the boiler clean?

Scale or sludge on the water side of the heating surfaces materially reduces the transfer of heat. Remove scale or sludge. Wash out boiler thoroughly. To prevent recurrence, chemical treatment of water may be necessary, in which case competent advice should be obtained.

5. Do you have exposed hot surfaces on boiler, piping, heaters, etc.?

Insulate hot boiler surfaces and increase thickness of existing insulation where necessary.

6. Are your gages, instruments and controls accurate and in good working order?

Be sure that needed instruments are provided and regularly checked.

7. Is the firing equipment in good condition?

All equipment should be kept clean, well lubricated, and in good repair for efficient operation.

8. Is your draft correctly regulated?

Correct furnace draft is necessary for efficient burning of the fuel. Too much draft results in higher flue-gas losses. Too little draft increases maintenance. Stop air leakage into breeching and chimney. Keep dampers and damper bearings in good condition. Provide convenient damper controls. Maintain furnace draft between 0.05 and 0.1 in.

9. Is reasonable care being taken to keep coal free from excessive water, snow and ice?

Excessive moisture in coal is wasteful. Protect your coal supply from the weather. Also see that it is properly stored so as to prevent spontaneous combustion which is wasteful and dangerous.

10. Are your automatic controls checked regularly?

Suitable automatic controls save fuel. Keep them in good operating condition to insure maintaining the proper fuel and air ratio at various loads.

11. Are you doing the best job of firing with the equipment and fuel being used?

Regardless of the equipment and fuel, careless firing methods waste fuel. A fuel saving of approximately 1 per cent can be attained by either increasing CO_2 content 1 per cent or decreasing the stack gas temperature 35 deg.

12. Do you have other losses?

There are other heat losses which waste fuel that can be prevented or reduced, such as, steam or hot water leaks, excessive blowdown, excessive popping of safety valves, excessive use of soot blowers, etc.

13. Do you have the manufacturers' operating instructions? Do you follow them?

The manufacturers of your equipment are best qualified to instruct you in correct methods of operation.

14. What are your suggestions for saving fuel and preventing waste?

Underfeed Stokers

a. Are your fuel beds maintained in uniform condition?

Fuel beds should be active and uniform over the entire area. Heavy and matted fuel beds produce smoke and result in damaged grates. Thin fires with holes are inefficient because of excess air that passes through.

b. Do you inspect the windbox regularly?

Coal siftings in the windbox interfere with proper air flow and waste fuel. Siftings are also a fire hazard. Remove these at regular intervals.

c. Do you maintain correct windbox pressure?

Operate with air pressure that will give the correct ratio of air and coal to maintain the highest CO_2 and lowest stack temperature practicable.

d. Are you banking your fires correctly?

Improper banking wastes fuel. Fire should be thinned down before banking. Feed all coal out of the hopper. Close the boiler damper gradually as the furnace cools.

e. Are you burning out combustible before dumping?

Unburned carbon discharged to the ash pit is a direct loss.

f. Do you remove refuse from the ashpits after each dumping?

Accumulation of refuse in ashpits wastes fuel by prolonging the dumping period. Clean ashpits after each dumping period so that accumulations will not interfere with operation of dump grates.

g. Do you keep the walls free of slag accumulations?

Remove clinker from walls at fuel bed level because it interferes with movement and combustion of fuel.

Traveling- or Chain-Grate Stokers

a. Are your fuel beds maintained in uniform condition?

If the air zones are functioning properly the burning rate will be uniform across the stoker in any given zone provided the fuel bed thickness and fuel size are uniform. Any deviation from a level bed, once established, indicates something is not functioning properly; check the level of the fuel gate and the possibility of segregation of coal sizes in the hopper.

b. Do you inspect the windbox regularly?

Coal siftings in the windbox interfere with proper air flow and waste fuel. Remove these at regular intervals. Siftings are also a fire hazard. Fires in the windbox may result in warped seals which cause air leakage between zones designed for proper distribution of air.

c. Do you maintain correct windbox pressure?

Operate with air pressure that will give the correct ratio of air and coal to maintain the highest CO_2 and lowest stack temperature practicable.

d. Are you banking your fires correctly?

Improper banking wastes fuel. The stoker should be stopped and the fires burned back to within 2 to 3 ft of the gate. The fuel bed should be thickened and run out about 10 ft from the gate. Close the damper gradually as the furnace cools. Grate should be moved periodically to keep the fire from burning back too far.

e. Do you clean grate surfaces periodically and remove clinkers?

Remove clinkers from walls at fuel bed level because clinkers interfere with movement and combustion of fuel.

Plugged grates prevent the free passage of air necessary for combustion, resulting in overheated grates. A jet of compressed air played on the grates will ordinarily remedy this situation.

f. Do you keep the proper relationship between grate speed and fuel-bed thickness?

Grate speed and fuel-bed thickness should be adjusted for best overall results. Short, thick fires with slow speed usually result in overheated grates and a tendency toward delayed secondary combustion.

g. Do you have the correct clearance between grate keys?

Keys should be spaced with just enough clearance for expansion, in order to equalize air flow and to avoid excessive siftings through the grate. Such siftings as occur should be returned to the furnace.

Spreader Stokers

a. Are your fuel beds maintained in uniform condition?

Check the depth of ash on grates and make sure all feeders are introducing the same amount of fuel. Adjust feeders to get uniform distribution from the front to the rear end of grates.

b. Do you maintain correct windbox pressure?

Operate with the air pressure that will give the correct ratio of air and coal to maintain the highest CO_2 and lowest stack temperature practicable.

c. Are you banking your fires correctly?

Improper banking wastes fuel. Several shovels full of coal should be placed in a mound at the forward end of the grate and allowed to ignite. The coal feed from the spreader unit is then stopped and the air cut off. Close the damper gradually as the furnace cools. (Note: The mound at the front is spread when starting up, to establish ignition.)

d. Do you collect and burn black cinders?

Fuel unburned is a direct loss. All reclaimable cinders should be collected and injected into the furnace.

e. Do you clean fires more often than necessary?

Allow the ash to accumulate to the maximum practical depth before cleaning. Too much ash makes cleaning difficult and prolongs the cleaning period. Study the operation and schedule cleaning best suited for your conditions. Clean one grate section at a time and burn out combustible before cleaning. When cleaning shut off the forced draft to this section and clean as quickly as possible.

f. Do you keep the walls free of slag accumulations?

Remove clinker from walls at fuel bed level, because it interferes with movement and combustion of fuel.

Pulverized-Coal Firing

a. Are burners maintained and adjusted properly?

Flame impingement results in unnecessary outages for maintenance.

b. Do you check the secondary air passages?

It is important to keep air passages to burners clear as the proper proportioning and mixing of air with coal is necessary to save fuel. Maintain burner throats and parts and adjust to secure proper mixing.

c. Do you check the fineness of pulverized coal regularly?

Improper fineness of coal wastes fuel. Maintain and adjust your pulverizing equipment to insure introducing coal of proper fineness.

d. Are your furnace walls free of excessive slag?

Such slagging raises gas temperatures throughout the unit and increases stack heat losses.

e. Are water sprays in the ashpit used more than necessary?

Excessive use of water in the ashpit wastes fuel.

Oil or Gas Firing

a. Are the burners maintained and adjusted properly?

Worn or damaged oil-burner tips and sprayer plates waste fuel. Oversized, oxidized or partly closed openings in gas burners waste fuel. These parts should be checked regularly and repaired or replaced.

b. Do you check the secondary air passages?

It is important to keep air passages to the burners clear, as the proper proportioning and mixing of air with oil or gas is necessary to save fuel.

c. Are the fuel pressure and temperature correct?

Lack of proper pressure and temperature wastes fuel.

Hand Firing

a. Are your grates in good working order?

Air slots in grates must be kept open. Do not let ash accumulate under the grates; it will stop the air from reaching all parts of the grates evenly and prevent uniform burning. In addition the grates will overheat and be destroyed if the air cannot circulate through them properly.

b. Are your firing methods the best for the particular fuel being burned?

When firing bituminous coking coals, heavy fuel beds usually result in matted beds with large coke masses which require excessive use of firing tools. Sometimes dampening bituminous coal slightly improves fuel-bed conditions. Study the "spreading" and "coking" methods of hand firing and use the method which works best for your conditions.

When firing anthracite coal, heavy beds are conducive to secondary combustion with corresponding loss in efficiency. Relatively thin fuel beds with more frequent feeding will produce better results.

Some over-fire air, immediately after firing fresh coal (leaving a hot spot for ignition of gases), is advantageous in burning combustible gases. However, excessive or unnecessary over-fire air wastes heat.

A fuel saving of approximately 1 per cent can be attained by either increasing CO_2 content 1 per cent or decreasing stack gas temperature 35 degrees.

c. Are you banking your fires properly?

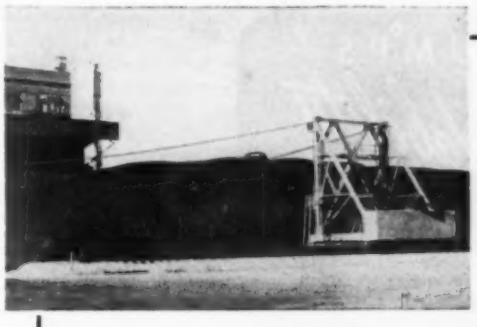
With bituminous coal, fires should be burned thin, and then fresh coal should be piled in a mound at the front of the grate. The damper is then closed. With anthracite burn down or clean the fire to get a thin bed; then spread a layer of fresh coal and crack the fire door to reduce fuel bed temperature. The damper is then closed. The banking operation, performed too suddenly, may cause clinkers or burned grates.

d. Are you burning out combustible before cleaning fires or dumping?

Unburned carbon in the ashes is a direct loss.

e. Have you considered the benefits to be obtained from mechanical firing?

In most cases a substantial saving in fuel (from 10 to 20 per cent) can be realized with mechanical firing over hand firing. Moreover, mechanical firing may permit the use of a wider range of coals



For rapid handling of large tonnage there are Sauerman Systems with self-propelled movable tail towers. The 7 cu. yd. Scraper System, illustrated above, now in operation for 16 years, handles an average of about one mill on tons of coal per year (both storing and reclaiming) for this 160,000 kw. generating station.

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Consulting Engineering Firm Reorganized

Since the passing of Geo. A. Orrok, the firm of Orrok & Myers has been reorganized for the continuance of consulting practice in the field of industrial power and allied problems. The senior member will be David Moffat Myers, long a consultant in industrial power, and with him will be associated Charles A. Fuller, an authority in heating, ventilating and air conditioning, and Herbert B. Addington, specialist in power plants. The old firm name will be continued, with Myers, Fuller and Addington as successors, at the same address—21 East 40th St., New York 16, N. Y. Enlarged facilities have been provided by joint offices and association being maintained with Binger & Hammond, architect engineers, with particular reference to jobs involving building design and power plant studies.

1944 National Power Show

Announcement has been made that the 16th National Exposition of Power and Mechanical Engineering will be held in Madison Square Garden, New York, November 27 to December 2, next. This year's event will be keyed to the effective solution of continuing war production problems, particularly those caused by sudden shifts in military needs, demanded by the ever-changing scenes in Europe and Western Oceania. It will also provide informational sources for the advancement of post-war planning.

More space has been provided than at the last Exposition in 1942, the number of booths has been increased and advance bookings up to the middle of July promise a greater number of individual displays than in 1942.

New Officers for Canadian Company

The Superheater Company, Limited, of Montreal announces the following changes in the management:

F. A. Schaff has been elected Chairman of the Board. He had previously served as senior vice-president from July 1920 to July 1940, and from then on as president. He is also president of the associate company, The Superheater Company of New York.

C. A. Odell was elected President. He became associated with the Company in 1919, as assistant to the late Andrew Loudon, then vice-president and has served as assistant secretary and assistant treasurer, manager and general manager. Mr. Odell came to the Company from the Canadian Pacific Railway and after Mr. Loudon's death he was elected vice-president on April 20th, 1926, which office he held until his election as President.

H. E. Brown was elected Vice-President. He has been with the Company since June 1926, previous to which time he was with the Canadian National Railways. He has been assistant to Mr. Odell, and general manager since March 1934 and will now be in charge of operations.

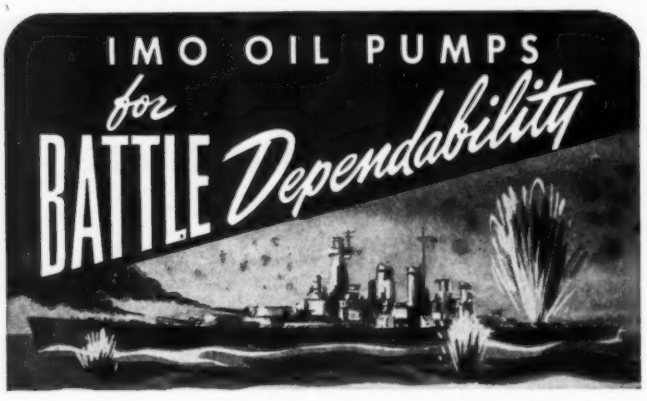
G. S. Thomson was elected Vice-President. He came with the Company in May 1916, and for the last twenty-four years has been manager of the works at Sherbrooke, Quebec.

N.A.P.E. Annual Convention

Plans have been completed for the Annual Convention and Power Show of the National Association of Power Engineers to be held in St. Louis, Mo., August 22 to 25, inclusive, with headquarters at the Hotel Jefferson. Missouri No. 2 Association will act as host. In addition to numerous committee reports, the program includes addresses by officers of the Association, local officials and several nationally known speakers. The theme of the exhibit will be "post-war power."

To Direct Coal Research

The expanded plan of Bituminous Coal Research, Inc. has brought about the appointments of **Dr. H. J. Rose** as Director and **E. R. Kaiser** as Assistant Director. The former was previously in charge of research for Anthracite Industries, Inc., and the latter came from the staff of Battelle Memorial Institute. For several years past Mr. Kaiser has been engaged in organizing support for the Bituminous Coal Research program in the capacity of assistant to the president of B. C. R.



A cruiser of the U. S. Navy, one of the classes of ships equipped with De Laval-IMO oil pumps.

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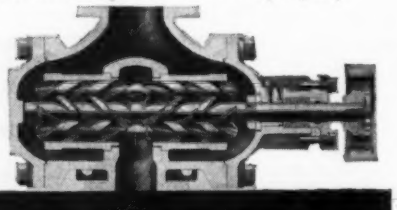

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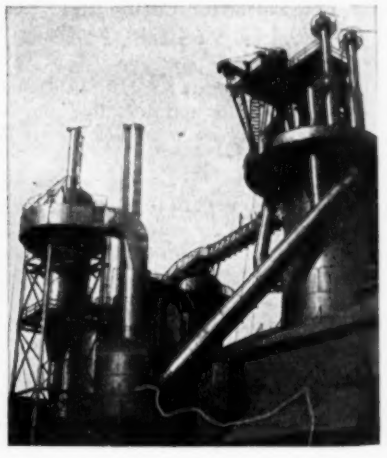

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REVIEW OF NEW BOOKS

Any of the books reviewed on these pages may be secured through Combustion Publishing Company, Inc., 200 Madison Ave., N. Y.

Centrifugal Pumps and Blowers

By Austin H. Church

The use of centrifugal pumps and blowers is axiomatic in almost every industry, yet the literature on this subject has been confined chiefly to technical papers and manufacturers' bulletins. For this reason the author, who is Associate Professor of Machine Design at New York University, has sought to provide a textbook which will serve as a reference work for young graduate engineers who have to deal with this type of equipment.

"Centrifugal Pumps and Blowers" covers the basic principles of design, construction and application along the lines of present-day practice. It does not attempt to develop new theories nor go into advanced problems, but references are given to many recent papers for more complete or advanced information. The text of the book is lucid and further clarified by numerous examples and excellent illustrations. Problems are given at the end of each chapter by which the reader may test his grasp of the subject matter.

The book contains 308 pages, size $5^1/_2 \times 8^3/_8$, and is bound in black buckram. Price $4.50.

Laying Out for Boiler Makers and Plate Fabricators—5th Edition

Revised by George M. Davis

Within the scope of firetube boilers and plate fabrication this book is a veritable encyclopedia of information for the boilermaker. Since it was first published in 1907, the subsequent editions have been augmented and enlarged to cover the rapid changes in boiler-making methods. The Fifth Edition has been revised by a boiler designer who specializes in locomotive boilers and this subject is particularly well handled in two new chapters.

The book contains thirteen chapters covering The Subject of Laying Out; Triangulation; Cones and Spheres; The Tubular Boiler; Laying Out the Locomotive Boiler; Constructing the Locomotive Boiler; Laying Out and Computing Boiler Patches; Laying Out for Welded Construction; Elbows; Layout and Construction of Steel Stacks and Tanks; Transition Pieces and Breechings; Pipe and Pipe Connections; and Chutes, Conveyors and Hoppers. The chapters on Boiler Patches and Welded Construction are also new.

The information in the book is presented in shop language and the problems are worked out without recourse to higher mathematics. The material is arranged progressively from simple to complex and the application of principles and methods is made clear by practical problems including all calculations necessary to determine the size of different parts.

The book contains 522 pages, size $8^1/_2 \times 11$, and is exceedingly well illustrated by many photographic halftones and more than 700 linecuts and drawings. Bound in stiff black buckram. Price $7.00.

Engineering Materials Annual

Engineering Production Annual

Edited by H. H. Jackson, A.F.R.Ae.S., M.I.E.I.

The exigency of war is responsible for the rapid advances made in many fields of engineering technology and, in recent years, the engineer has had difficulty in keeping himself informed of progress in technological fields other than his own. The need for a reliable and comprehensive record, or index, of such developments has long been known and the British publisher of this series of Development Reference Annuals is to be commended for undertaking this particular task. In their respective fields, these two slim volumes—Engineering Materials Annual and Engineering Production Annual—comprise a complete and concise record of all important development work carried out or gleaned from hundreds of articles, bulletins, lecturers, etc., during the past year or two.

"Engineering Materials Annual (1)" contains 12 chapters covering Iron and Steel, Non-Ferrous Metals, Plastics, Rubbers (Natural and Synthetic), Solid Fuels, Gaseous Fuels, Ceramics, Lubricating Oils and Greases, Glass, Plywood and Adhesives, Precious Metals, and Refractories—each compiled by a technical editor specializing in his field. The brief text in each chapter is followed by a comprehensive list of references as to source material and, in some instances, pertinent British and American patent numbers are given; also a listing of recently published books.

"Engineering Production Annual (1)" contains 13 chapters covering Machine Tools, Cutting Tools, Cutting Oils and Compounds, Quality Control, Deep Drawing and Pressing, Surface Hardening and Heat Treatment; Hard-Facing, Surface Protection, Inspection Methods, Welding, Soldering and Brazing, Bearing Metals, and Powdered Metallurgy.

Each volume comprises more than 100 pages size 5×8, bound in stiff covers. The price of each volume is $2.00; delivery in about 8 weeks.

The Second Mile—A Re-Survey

By W. E. Wickenden

In 1941 W. E. Wickenden, President of Case School of Applied Science, delivered a memorable address before the Engineering Institute of Canada entitled "The Second Mile." In this he sought to promote professional consciousness among engineers by discussing professional traditions and obligations, the philosophy of the engineer, his relation to society and that extra effort which he characterized as "The Second Mile" wherein men should strive for special excellence in their chosen work.

Since the war has introduced factors that seem likely to confuse the post-war professional status of engineers, President Wickenden has been induced to re-survey his previous address with special reference to the young engineer. This new version is fully as interesting as the original and in anticipation that it will be as well received, the Engineers Council for Professional Development, 29 West 39th Street, New York, is prepared to furnish copies of this 15-page pamphlet in lots of one hundred for $3.00; in small lots at 5 cents per copy; or 10 cents for single copies.

Results of Publicly-Owned Electric Systems—1944

By Burns & McDonnell Engineering Company

This is the eighth edition (1944) of an electric rate book showing the operating records, earnings, rates, net revenue, valuation and other information as to the use and cost of electricity in 767 publicly-owned systems. The type of plant, whether steam, diesel or hydro, and its form of management are also recorded.

The new volume has several interesting charts and tables showing rates and revenue. It contains new information showing a comparison of the rates of both private and municipal plants in every city of over 5000 population. Over half the publicly-owned systems in the country have lowered their rates since the last (1941) edition appeared, and a majority of the 767 systems listed report "no bonded indebtedness."

The book contains 450 pages, size 6 × 9, with brown paper covers and white plastic binder. Price $10.00.

Questions and Answers for Marine Engineers—2nd Edition

Compiled by Captain H. C. Dinger, U.S.N. (Retired)

This revised edition combines Books III, IV and V previously published under the titles "Auxiliaries," "Application of Steam and Heat in Producing Power," and "Powering, Fuel Economy, Propulsion, Propellers and Shafting." Originally this material appeared in the Question and Answer department of *Marine Engineering and Shipping Review*. Anyone preparing for his license examination will profit considerably from the study of the 26 chapters contained in this volume.

The book, size $5^1/_8 \times 8^1/_8$, contains 330 pages and includes a 4-page index. Bound in paper covers the price is $2.00; in cloth covers, $2.50.

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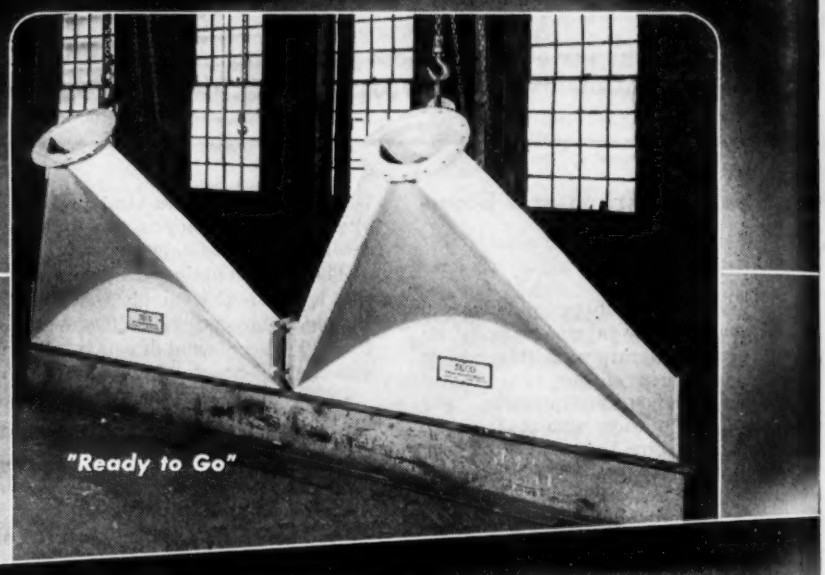

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